Industrial Allocation and Growth Trajectories: A multi-level approach

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To my friends

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Declaration

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text.

This thesis does not exceed the regulation length, including footnotes, references and appendices.

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Summary

This dissertation investigates the process of economic growth with heterogeneous agents from a multi-level perspective. Building upon Kaldorian and Evolutionary principles, growth is defined as a path-dependent and complex phenomenon, which requires structural variation and the interplay between demand and supply at distinct analytical levels. Two concomitant and dependent 'layers' of this process are emphasised: the supply-led 'intra-sectoral development trajectory' and the demand-led 'inter-sectoral development trajectory'. The key element in the first is the firm size, which is shown to have a non-linear influence on the process of technological change. The second layer is shown to depend on the growth of income and patterns of production and consumption reflected on the inter-sectoral composition and level of 'sophistication' of the productive structure. The key to understand divergent growth trajectories lies in the interaction between these layers and the contradictory effects imposed at each analytical level both by demand (top-down) and supply (bottom-up).

The approach is both theoretical and empirical and the analysis reveals important stylised facts of growth at the firm, sector and country levels. The text is structured in four sections comprising 9 chapters. Section I introduces the theoretical foundations of the work and the limitations of Evolutionary and Kaldorian schools to explain the multi-level 'allocation problem'. Section II presents the databases and empirically assesses the influence of the (re)allocation of labour on growth at each analytical level. Section III investigates the foundations of the process of micro-meso and macro process of development. The final section proposes a unified theoretical framework to connect the multi-level evidence. The analysis reinforces the interplay between demand and supply in growth trajectories, prompting a number of original policy implications.

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Introduction

The so-called 'allocation problem' originates in divergent trajectories of productivity for different economic units, such as firms, sectors, and/or countries. The phenomenon is caused by discrepancies in either the technology of production and/or demand for the product of these units. Ultimately, the competitive advantage ensued by these 'structural heterogeneities' make the (re)distribution of factors across firms and sectors a key element for economic growth (Maddison, 1987).

Relegated to the 'structural' and 'industrialisation literatures' (Chenery, 1960; Abramovitz, 1983; Syrquin, 1988), the topic was recently revised by a number of studies at a varied analytical perspective. At the inter-sectoral level, studies in the broad Structuralist (McMillan and Rodrik, 2011; Timmer and Szirmai, 2000) and Schumpeterian traditions (Fagerberg, 2000; Hausmann, Hwang and Rodrik, 2007; Hausmann and Hidalgo, 2011) calls attention to the central role of manufacturing composition to growth. At the intra-sectoral analytical level, the so-called 'misallocation' studies – a branch of the neoclassical industrial organisation literature – highlights the impact of the distribution of factors across [and within] firms in the country's total factor productivity[1] (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008, Bartelsmann *et al*., 2009; Baily and Solow, 2001).

The important implications of these studies have been recognised by both mainstream and non-neoclassical audiences (Jones, 2011; McMillan and Rodrik, 2011). Notwithstanding, the foundations of the 'new allocation literature' were rarely object of theoretical scrutiny. In fact, dissimilar and, in most cases, non-compatible assumptions support the findings of these studies[2]. Besides, neither macroeconomic nor microeconomic approaches considered how these findings at different analytical levels are connected. As argued in this study, the recent redemption of the allocation problem in economics still lacks a theoretical body to justify and connect the evidence in one framework.

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[1] The evidence collected in the misallocation literature suggests that differences in the distribution of firm sizes account for between 25% to 60% of the cross-country differences in TFP (Jones, 2011).
[2] Indeed, the misallocation literature finds the culprit of the structural heterogeneity in policy distortions, whereas for the Schumpeterian and Keynesian macro-approaches sectoral divergences in the dynamics of the innovation process (supply) and by the demand for manufacturing are the causes, respectively.

This dissertation aims to fill this gap in the literature. For that, it proposes a requalification of the origins and role played by the so-called 'structural heterogeneities' in economics. Building upon Evolutionary and Kaldorian principles, growth is presented as a complex and path-dependent process that requires and prompts 'variation' in the system (Nelson and Winter, 1982). As long as these are reflected in the 'ecosystem' of firms and sectors composing an economy, the path of development can be reconstructed from the analysis of the process of structural change (both across and within sectors).

In the chapters to follow, the process of economic development is separated in two interdependent processes of transformation, namely: the 'intra-' and 'inter-sectoral development trajectories'. Each constitutes a different layer of the growth process, with its own dynamics and determinants. The first is shown to be led by the supply-side dynamics, being ultimately dependent on the level of concentration of the market-structure (given the sectoral technological paradigm). The second is led by the dynamics of demand, which is represented by consumption patterns reflected in the sectoral composition and determined by the level of income.

The key to growth is to be found in the interplay between these two trajectories. The intra-sectoral development process, which requires the concentration of the market-structure, fosters the development of the productive forces of the economy, increasing income levels. At the inter-sectoral level, the rise of income encourages the opening of technological opportunities with new (more sophisticated) sectors, at the same time that it fosters the de-concentration of the market-structure, reducing the intra-sectoral process of technical change. The final (divergent) growth trajectory is thus shaped by these top-down and bottom-up forces, being ultimately dependent on the level of constraints imposed by each demand and supply in the process of development.

The Evolutionary and Kaldorian literatures provide the theoretical foundations for the supply and demand requisites, respectively. Despite the contrasting view on the engine of the growth process, a number of parallels can be traced between these two economic schools[3]. Indeed, merging the contributions of these schools is not new in the literature. Since Cornwall (1972), a number of

[3] Firstly, they both see growth as an endogenous and path-dependent process (McCombie and Thirlwall, 1994; Romer, 1990; Nelson and Winter, 2002). Secondly, economic heterogeneities are acknowledged and seen as a dynamic source of growth prompting divergent and not only convergent patterns of development. Lastly, both of these frameworks can be easily adapted to improve the representation of either demand and/or supply.

studies has been pursuing an improved representation of the supply side in the Kaldorian framework (Cornwall and Cornwall, 2002; Palley, 2002; Setterfield, 2013; Romero, 2015). At the Evolutionary literature, a growing branch of studies have been exploring the feedbacks between demand and the process of technical change (Peneder, 2003; Castellacci, 2009; Dosi, Fagiolo and Roventini, 2010; Verspagen, 2002).

This dissertation is contributory to this growing literature. Among its important contributions, one should highlight: (i) the original perspective of the development problem, treated as a multi-level phenomenon; (ii) the original use of Evolutionary and Kaldorian elements for the explanation of the multi-layered process of development; (iii) the unprecedented association of the dynamics of demand and supply with each of these specific layers of the process of development; (iv) the seminal investigation of the foundations of the Kaldorian growth model, particularly of the elements representing demand and supply in the framework: returns to scale and demand elasticities; (v) the seminal application of growth accounting and econometrics in the empirical assessment of the importance of structural heterogeneity and structural change for growth at both the intra-sectoral and inter-sectoral levels.

This dissertation is structured in four sections comprising 9 chapters. Section I introduces the theoretical foundations of the work and the limitations of the approaches. Section II presents the intra-sectoral and inter-sectoral databases and assesses the influence of (re)allocation on growth at each analytical level. Section III discusses the development process at each of the layers and empirically assesses their fundamentals. The final section explores the interplay of demand and supply and proposes an Evolutionary-Kaldorian transformation model that summarises the influence of these elements on growth trajectories. The approach and specific contributions of each chapter are summarised below.

Chapter 1 reviews the Evolutionary literature and discusses the concepts supporting the analysis of both the intra- and inter-sectoral development processes. Conceived as a non-neoclassical theory of technical change (Dosi, 1982), the Evolutionary approach sees in the variegated, path-dependent, stochastic and complex process of innovation the engine of growth. Two particular approaches are of special relevance in the context of this dissertation:

(i) The micro-meso studies based on Schumpeter's (1942) 'Mark 2 model', which emphasise the role of firm size in innovation trajectories. According to Schumpeter, large firms enjoy of a privileged condition in the innovation competition, "*for there are advantages which, though* *not strictly unattainable on the competitive level of enterprise, are as a matter of fact secured only on the monopoly level*" (Schumpeter, 1942 p.101). These technological advantages respond to the scale of the internal innovative activities, that is, the number and quality of brains, structure, and sphere of influence of the firm. Even though neither a necessary nor sufficient condition for innovation, the Schumpeterian hypothesis[4] establishes that the firm size dictates the rhythm with which the process of technical change takes place at both firms and sectors (e.g., Nordhaus, 1969; Nelson and Winter, 1982; Cohen and Klepper, 1996).

(ii) The meso-macro studies on productive/trade specialisation and economic complexities: inspired on Schumpeter's (1934; 1942) notion of technological competitiveness and other systemic approaches, these see different productive units (sectors) as embodying specific capabilities (e.g., Malerba, 1995; Verspagen, 1992; Hausmann, Hwang and Rodrik, 2007; Hausmann and Hidalgo, 2011). As the visible facet of such capabilities, the sectoral composition of the economy and the process of structural change are key elements in the growth explanation.

Even though the Evolutionary principles of innovation variety and path-dependence provide the basis for understanding the allocation problem in its multiple levels, the current paradigm in this literature neither can explain the misallocation findings at the intra-sectoral level, nor how the intra-sectoral and the inter-sectoral allocation problems are connected. It is argued that three important gaps need to be tackled before an answer is available. Firstly, the adoption of meso rather than micro foundations in the analysis of the growth process (Dopfer, Foster and Potts, 2004). Secondly, a re-signification of the role played by firm size in technological trajectories (Castellacci, 2003). Finally, the re-qualification of the role played by demand in the innovation and growth processes (Verspagen, 2002). This dissertation aims to address each of these limitations.

Chapter 2 introduces the Kaldorian theory and discusses its appropriateness for the study of the multi-sectoral growth phenomenon. Building on Keynes (1936) and the seminal contributions of Young (1928) and Verdoorn (1949), Kaldor (1966, 1970, 1972) conceived a demand-led system where growth is cumulative and circular. Among his contributions to the growth theory, also known as Kaldor laws, one should highlight: (i) the growth of GDP responds to the growth of the

[4] As the advantages of large firms were named in the literature.

manufacturing sector; (ii) the productivity of the manufacturing sector responds positively to the sector's output growth; (iii) finally, as a corollary of these two laws, the productivity of the non-manufacturing sector is also positively correlated with the growth rate of the manufacturing sector. These laws are especially relevant in the context of this work[5]. Firstly, because they establish the notion of structural heterogeneity as an innate condition of the economic environment. Secondly, because they make growth dynamically associated with the process of structural change. Finally, because they set the element responsible for the structural differentiation: the concept of returns to scale, which derives from the singular characteristics of the demand for manufactures.

Perhaps the most important contribution of the Kaldorian approach for the demand-led growth theory lies on the necessary interplay between demand constraints and supply conditions in the growth process. The ensuing development of the Kaldorian principles led to the establishment of important tools to assess these, particularly: (i) the Verdoorn coefficient, a measure the technological progress in the economy; and (ii) the elasticities of demand, the ultimate constraints to growth. While focusing on these elements, the chapter introduces the canonical models in the literature and discusses how changes in demand and supply regimes can modify the model's response. The limitations of the approach are addressed in Chapter 8.

Section II investigates the level of productive heterogeneities in the manufacturing sector worldwide and the importance of labour reallocation for growth at each analytical level. The approach aims at providing empirical justification for studying the allocation problem in its multiple levels.

Chapter 3 focuses on the inter-sectoral analytical level. The analysis is underpinned on an extensive database (UNIDO), which comprises 125 industrial branches and covers 18 years (1991-2009) and 42 countries. The adoption of a production database in these exercises is per se an important contribution since most studies resort on trade data. The chapter explores the structural heterogeneity in manufacturing branches through comparative and descriptive exercises. Although these are traditional methodologies, the study merges the contribution of various authors as Salter (1960), Fagerberg (2000), Kuznets (1956), Chenery (1960) and Denison (1967). Finally, two different growth accounting exercises (shift-share and counterfactual) and an econometric exercise assess the

[5] Note that they also represent a significant rupture with traditional growth theory for growth is accept as demand-led process (Thirlwall, 2003). Also, in this context, the production function loses significance, as movements along and across the curve become indistinguishable (Kaldor, 1970).

impact of labour reallocation on productivity growth. The results show that the impact of structural change on growth depends on the sectoral breakdown of the data. This reveals that most of the evidence found in the literature, which is based on aggregated databases, can be misleading. The approach also uncovers a number of interesting growth patterns.

Chapter 4 shifts the analytical perspective to the intra-sectoral level and investigates the extent to which the distribution of firm sizes affects growth. The analysis is based on the Structural and Demographic Business Statistics (SDBS) database, which comprises 17 years of data (1991-2007) disaggregated in five size classes of 2-digit ISIC sectors for 36 countries. Following Chapter 3's analysis, comparative and descriptive exercises assist in the investigation of the pervasiveness of the intra-sectoral heterogeneity. Country-level counterfactual and shift-share exercises assess the relative importance of the intra-sectoral reallocation process to productivity growth. Finally, a multi-sectoral econometric growth model is introduced and different panel data methods are used to estimate its parameters. This study contributes to fill a gap in the non-neoclassical literature. At the same time, the approach presents a series of advantages compared to the neoclassical misallocation approach, especially (i) because the counterfactual exercise requires weaker hypotheses when compared to the original misallocation exercise, but also because (ii) differently from the misallocation and counterfactual exercises, which only inform the relative importance of the intra-sectoral allocation for growth, the shift-share and econometric exercises convey the actual impact of the first on the latter.

Section III comprises 4 chapters focusing both on overcoming the theoretical limitations of the literature to explain the multi-level allocation problem, and the empirical investigation of the intra- and inter-sectoral development trajectories and their determinants.

The intra-sectoral development trajectory is discussed in Chapter 5. The approach revisits the seminal Evolutionary perspective on the relationship between firm size, innovation and growth to show how the Evolutionary ideas can explain the empirical patterns recently unearthed by the misallocation literature. The firm size is shown to simultaneously affect and be affected by the process of technical change. Such a perspective of the sectoral development process is rather innovative and involves different hypotheses that are promptly tested. The main contributions of this chapter are summarised as follows: (i) advancing an explanation for the long-term and dynamic impact of the intra-sectoral allocation on sectoral growth; (ii) showing that the firm size trajectory represents an important meso-foundation of the process of growth; (iii) empirically assessing the foundations of the relationship and its impact on sectoral growth trajectories; (iv) building the basis for the investigation of the importance of firm size distribution for innovation and growth, which is further explored in the next chapter.

Chapter 6 re-assesses the role of firm size in development trajectories from a multi-sectoral perspective. For that, it proposes a general, but flexible function of technological progress, which is calibrated to reflect sector-specific characteristics determined by the knowledge base (Pavitt, 1984). Such a representation has the advantage of preserving the role of firm size in these trajectories while acknowledging sectoral differences. Yet, the actual evolution of sectoral concentration in development trajectories is shown to depart from the logistic path determined by the function of technological progress. Profiting from the versatility of the Kaldorian analytical framework – in special of the structural parameters representing each the demand and supply requisites for growth – the chapter estimates the Verdoorn coefficient[6] and income elasticities for different firm size classes. The investigation leads to two important conclusions: (i) the Verdoorn coefficient shows that returns to scale increases logistically with firm size, as proposed by the model; (ii) the income elasticities, however, decrease with size, being particularly low for large firms, which explains why the market-structure of developed economies are less concentrated compared to developing economies. These results confirm that the intra-sectoral potential trajectories are supply-led. Nevertheless, the unaccounted influence of demand constrains the sectoral development trajectory, altering the final composition of the market-structure. This explains much of the controversy around the empirical validity of Schumpeterian hypothesis in the literature. Such an approach has yet another important contribution: by investigating the foundations of the Kaldorian parameters, it casts light on an important limitation of this literature.

Chapter 7 explores the foundations of the inter-sectoral development process. Based on the meso-macro discussion developed in Chapter 1, the proposal ratifies the complementarities between the Structural and Evolutionary literatures. The process of development of manufacturing is presented as an ordered process of accumulation of capabilities and learning. The association between these capabilities and specific sectors makes the sectoral composition of the economy the visible facet of this process. The results show that the manufacturing development process involves both an

[6] Although much of the recent efforts in the Kaldorian literature are destined to explore the foundations of these parameters, to date, Verdoorn's law and income elasticities have never been assessed at the intra-sectoral level.

'absolute diversification' of the productive structure and the 'relative specialisation' in more sophisticated/rare products, justifying the 'complex' approach. Among the contributions of this chapter, one may highlight the following: (i) it deepens the discussion concerning the fit of the Evolutionary theory in explaining the process of industrial development; (ii) it seminally adapts the 'method of reflections' proposed by Hausmann *et al*. (2007) for the application to an industrial database; (iii) it typifies and brings new evidence on the importance of patterns of specialisation for manufacturing growth dynamics.

Chapter 8 concerns the adaptation of the Kaldorian model for the study of growth with heterogeneous agents. Revisiting the Kaldorian function of technological progress and hysteresis ideas, the chapter advances towards a model in which the endogenous process of structural change is the key for growth. The reconstitution of the supply side is helped by the Evolutionary ideas developed in the previous chapter, following some recent studies (Cornwall and Cornwall, 2002; Palley, 2002; Setterfield, 2003; 2013; Romero, 2015). The approach is corroborated by the estimation of both Verdoorn's coefficients and sectoral income elasticities for each of the categories of product sophistication (complexity) defined in the previous chapter. The empirical results show that income elasticities are closely related to the level of structural complexity, while the Verdoorn coefficient has a quadratic (inverted U) relationship with the latter. Confirming last chapter's conclusion that the productive structure evolves towards the structural sophistication, these results suggest both (i) that the inter-sectoral development trajectory is led by the demand dynamics, and (ii) that the supply dynamics has a contradictory effect on the sectoral specialisation, favouring intermediate-sophistication sectors. By investigating the foundations of the Kaldorian parameters, this chapter contributes to fill an important gap in this literature.

The final chapter of the dissertation assesses the interplay between demand and supply trajectories in each of the layers and proposes an Evolutionary-Kaldorian transformation model that synthesises the influence of these elements in growth trajectories. The analysis shows that the intra-sectoral development process, which requires consolidation, fosters the development of the productive forces of the economy, increasing income levels. At the inter-sectoral level, the rise of income encourages the opening of new technological opportunities in new (more sophisticated) sectors, but, at the same time, fosters the de-concentration of the market-structure, reducing the intra-sectoral process of technical change. The key to economic growth is to be found in the interaction between these layers and the contradictory effects imposed at each analytical level both by demand (top-down) and supply (bottom-up). Finally, a multi-sectoral model of Kaldorian inspiration explains the development process. The model synthesises the multi-level development trajectory previously discussed with a multi-sectoral framework and tests the impact of different policies in the traverse. Although simpler, the approach is still accurate when compared with complex, multilevel and agent-based analyses typically found in the Evolutionary literature.

The final chapter reiterates the contributions and limitations of the approach and addresses some open questions. A number of policy implications and extensions are also highlighted.

1 Innovation Variety, Path-Dependence and Growth: The Evolutionary Perspective

1.1. Introduction

The Evolutionary school is the branch of the Schumpeterian theory that, inspired by Darwinian ideas, stresses the role of both resilience and 'variation' in the process of growth. It is the combination of these factors – 'hysteresis' and 'non-homogeneous productive factors' – that shape the most distinguishable characteristic of this theoretical body: the assignment of singular technological trajectories to distinct productive units.

Amongst the varied emphases in the Evolutionary literature, two are particularly relevant for the purposes of this dissertation: (i) the micro and meso-level studies on innovation variety and technological progress, which argue that the firm size and composition of the market-structure are the key elements in the innovation process (Nelson and Winter, 1982); and (ii) the meso and macro-level studies on 'economic complexities' and patterns of specialisation, which highlight the role of the sectoral composition in growth trajectories (Hidalgo *et al.*, 2007). The concepts and ideas in each of these lines of study are the basis for the multilevel development story unravelled in the following chapters.

This chapter introduces the main ideas and concepts behind each of these lines of study. Section 1.2 focuses on the microeconomic literature, highlighting the connection between the firm size and market-structure and their role in intra-sectoral growth trajectories. Section 1.3 focuses on the meso-macro literature, highlighting the concept of product sophistication [economic complexification] and its role in the process of inter-sectoral development. A critical assessment of the empirical literature is offered by the end of each section. Section 1.4 concludes the chapter by summarising the contributions and gaps in the literature.

1.2. Business size, intra-sectoral heterogeneity and technology progress

The Evolutionary school borrows its name from the Darwin's Evolution theory, where path-dependency (cumulativeness) and variety are central in the process of development. As a branch of the supply-sided Schumpeterian theory, the Evolutionary school sees in the process of technical change the ultimate source of growth. The school advocates the endogeneity of growth in the process of learning where the basic unit, knowledge, accumulates in tangible and intangible assets (Griliches, 1979) to shape a range of distinct technical competencies (know-how, capabilities, expertise, etc).

In a parallel with the Darwinian's notion of variety, the 'innovation variety' dictates the rhythm of the process of innovation and growth. The notion originates in the non-homogeneity of the factors affecting either the generation[7], accumulation and/or the spread of innovation in a particular economy. Amongst the most important sources of heterogeneity, one may highlight context-specific elements such as production interdependencies, local competition characteristics and resource constraints (Dosi, 1988). Accordingly, understanding and classifying the variety of technological competencies and innovation patterns has always been a central theme in this literature[8].

The emphasis on the influence of the market-structure in shaping innovation refers back to the publication of Schumpeter's seminal work. In *The Theory of Economic Development* (1934), Schumpeter proposed an innovation regime starred by small firms and new entrepreneurs. In this 'entrepreneurial' or 'widening' regime – also known as 'Schumpeter Mark 1' – the easy of entry and the low concentration of innovation activities would give rise to a process of 'creative destruction', where the ideas brought about by entrants foster constant technological disruptions. In this turbulent market, successful newcomers reap all 'quasi-rents', favouring a deconcentrated market-structure .

Inspired by the increasing evidence on large businesses disproportional expenditures in R&D, in *Capitalism, Socialism and Democracy* (1942), Schumpeter proposed a competing innovation regime named of 'creative accumulation', which is led by large and established firms. The key in this 'deepening' or 'routinised' regime – Schumpeter Mark 2 – is in the accumulation of knowledge,

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[7] Innovation can be the result of (i) formal procedures of search, such as R&D investment (Nelson and Winter, 1982), (ii) the acquisition of embodied technology, as in the form of new machinery (Evangelista, 1999), or even (iii) informal processes of learning-by-doing (Arrow, 1962), learning-by-using (Rosenberg, 1982) and learning-by-interacting (Lundvall, 1988).

[8] The sources of innovation variety are usually generally classified by: (i) competitive strategy (technological competitiveness, cost competitiveness, etc); (ii) means of acquiring knowledge (R&D, acquisition of patents, purchase of machinery and equipment, learning by doing or using, imitation, etc); (iii) introduction of innovations (products, processes, organisational change, etc; (iv) knowledge protection (patents, design/image strategy, industrial secret, etc); (v) collaboration strategies (with universities, research centres, customers, or other firms, as suppliers or even competitors); (vi) level of internationalisation; (vii) level of human capital, etc..

resources (financial inclusive), and competences. These assets serve as entry barriers and contribute to keep a stable population of firms in an oligopolistic environment.

Although the Evolutionary literature historically focused on the empirical validation and expansion of these archetypes[9], recently, the [empirical] requalification of the concept of innovation[10] led to the incorporation of other determinants in the analysis, resulting in a progressive decline of the role played by the market-structure in innovation trajectories. Indeed, the sectoral studies in the Evolutionary tradition evolved towards the acknowledgment of the endogeneity of both market-structure and innovation strategies in the 'knowledge-base'[11]. The latter differs for distinct production chains, shaping the technology at use in each environment.

Four major lines of research can be distinguished in this micro and meso-level literature:

(i) The 'market-structure and innovation' emphasis (Kamien and Schwartz, 1982; Cohen, 1995).
(ii) The 'technological regime' approach (Nelson and Winter, 1982; Dosi, 1982).
(iii) The 'innovation patterns' or 'technological trajectories' approach (Rosenberg, 1979, 1982; Pavitt, 1984; Levin *et al*., 1987; Nelson, 1993; Mowery and Nelson, 1999).
(iv) The 'innovation systems' approach (Malerba, 2005).

This section discusses the evolution of the role of market-structure and firm size in innovation trajectories in this literature. The firm size, as it will be explored in Chapter 5, is closely connected with the technology level of the production. As such, it is a key element for understanding the evolution of the supply-side in a particular market.

1.2.1. Market-structure and innovation: the 'Schumpeterian hypothesis'

The seminal Evolutionary studies concerned the relationship between firm size, monopoly power and innovation (cf. Nordhaus, 1969; Scherer, 1970; Nelson and Winter, 1982; Cohen and Klepper, 1996). The accumulation of evidence on the association between firm size, R&D spending and innovation led many authors to argue that the concentration of R&D in large firms as a direct consequence of the superior capabilities of these in the innovation competition. The 'Schumpeterian

[9] Some authors associate each to specific technological paradigms (Malerba and Orsenigo, 1993) or stages of the overall process of sectoral development (Breschi, Malerba and Orsenigo, 2000).

[10] Reflecting the lack of data on technological progress, the early Schumpeterian studies adopted a narrow definition of innovation, which confined the process to R&D investment towards the discovery of new-patented-products. In its most recent meaning, the concept includes a variety of strategies followed by firms with the aim of improving its production process or expanding market.

[11] The characteristics of the knowledge at a specific production chain (see Section 1.2.2).

hypothesis', as the advantages of firm size was later named, establishes that (even though neither a necessary nor a sufficient condition) the business size ultimately dictates the rhythm with which the process of technical change takes place at both firm and sector, by consequence.

According to Schumpeter (1950), large firms dispose of economies of scale in R&D and management, but also greater capabilities for risk spreading, finance, and a larger sphere of political influence. The technological advantages of large business, however, accrue from the process of innovation itself. As a path-dependent and cumulative process, innovation depends on the firm's previous achievements, or the level of capabilities accumulated over the process of development, which is highly correlated with the firm size. At the same time, requirements of indivisibility and economies of scale, especially in R&D projects, favour large firms and their greater innovation contingency[12]. The larger scale R&D also improves the organizational efficiency of these activities (Cohen and Levin, 1989). The intrinsically risky and uncertain nature of innovation also tends to discourage smaller firms' expenditures, especially if financial markets are imperfect. In this case, funding is distributed unevenly and the lack of collateral worsens the risk in small business loans (Nelson and Winter, 1982).

Moreover, the firm size is not only an indicator of the level of internal economies of scale, but also of the capacity of internalising external economies. Undertaking in-house R&D is key for forging 'absorptive capacity' in the firm, increasing its capacity to benefit from external. Innovative firms, therefore, are those who benefit the most from external economies (Geroski and Machin, 1992). Furthermore, large firms also benefit from economies of scope. Firstly because a diversified R&D portfolio increases synergies, promoting the cross-fertilization of ideas, but also because their greater output and market share contribute to reduce failure risks, since they enhance the commercial exploitation of innovation at different markets and/or production fields (Kamien and Schwartz, 1982; Baldwin and Scott, 1987; Cohen and Levin, 1989).

The implication of these technological advantages of large firms exceeds the firms themselves, shaping entire sectors. Since, successful businesses tend to overrun their competitors' market, within the boundaries imposed by the knowledge base, market concentration is an unavoidable by-

[12] The establishment of specialist research institutions and the pursuit of innovation in a systematic basis, both of which depend on the level of R&D investment, are largely associated with good innovation outcomes (Cohen, 1995).

product of technological progress[13]. It is argued that the consolidation of sectors in fewer firms may actively contribute to accelerate growth, as it reduces the 'investment congestion' or duplicative R&D that decreases welfare levels (Cohen, 1995). Likewise, it also enhances external economies of scale since these rapidly expanding firms inspire competitors, fostering both imitation and innovation[14]. At the aggregate level, 'a market-structure involving large firms with a considerable degree of market power is the price that society must pay for rapid technological advance' (Nelson and Winter, 1982 p.278).

For it challenges ideas long established in economics such as the advantages of competition, the welfare costs of monopoly, and the importance of R&D variety for innovation[15], the Schumpeterian hypothesis has always been controversial. The support of the hypothesis varied in time, reaching an apex with t first generation of Evolutionary studies. This was supported by the evidence, as summarised in Kamien and Schwartz (1982), Scherer (1980): (i) the likelihood of performing R&D rises with firm size; (ii) R&D and firm size are closely and positively correlated within industries; (iii) R&D rises in proportion with firm size in most industries.

However, a more recent empirical literature (Baldwin and Scott, 1987; Freeman and Soete, 1997) has nonetheless identified that (iv) the number of patents or innovations per dollar invested in R&D decline with firm size, and some studies even suggest that (v) large enterprises do not account for a disproportionate amount of R&D relative to their size (Scherer, 1992). These ambiguous evidence contributed to invigorate the 'size scepticism' in the literature (Cohen and Klepper, 1996).

Although demonstrated by Cohen and Klepper (1996) that the ambiguous evidence originates in the measurement of innovation[16], methodological shortcomings[17] and the rather disseminated use of

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[13] This conclusion has been extensively tested in simulation exercises in Nelson and Winter (1982).

[14] At an individual level, small firms are those who, arguably, benefit most from this process (Cohen and Klepper, 1996).

[15] The evidence shows that the number of innovation projects increases with the number of firms in an industry (Sah and Stiglitz, 1988).

[16] The authors use the idea of cost spreading to explain the empirical puzzle of why large firms conduct more R&D if they generate fewer results. According to them, both because past and future output are not independent from one another, and because the outcome of R&D cannot be fully licensed –sold in a disembodied form (Arrow, 1962) – then "*the larger the firm then the greater the output over which it can apply the fruits of its R&D and hence the greater its returns from R&D. Alternatively stated, the larger the firm then the greater the level of output over which it can average the costs of R&D*" (Ibid, p.926).

[17] Among which the problem of reverse causality, for size is both the cause and outcome of a successful innovation.

R&D (input) and/or patents (output) as measures of innovation[18], contributed for dislodging the Schumpeterian hypothesis from the core of the recent Evolutionary studies.

1.2.2. Technological regimes and the endogeneity of the market-structure and innovation

The works of Dasgupta and Stiglitz (1980) and Nelson and Winter (1979), but especially the publication of *An Evolutionary Theory of Economic Change* by Nelson and Winter (1982) revolutionised the Schumpeterian perspective on the relationship of market-structure and innovation. Firstly, they criticise the early tradition of Schumpeterian studies for not acknowledging the mutual causation of these elements. Secondly, they advocate that the dynamics of both innovation and market-structure is determined by the process of market selection and by the nature of technology, which differ greatly across 'technological regimes' (Nelson and Winter, 1982; Winter, 1984).

A technological regime defines the conditions in which firms' innovative activities take place. In each sector of the economy, distinct elements affect the direction and intensity of learning processes and the knowledge accumulation (Castellacci, 2007).

> "*[A technological regime] set the boundaries of what can be achieved in firms' problem solving activities and identify also the 'natural trajectories' along which solutions to these problems can be found [...] The notion of technological regime provides a synthetic way of representing some of the most important economic properties of technologies and of the characteristics of the learning processes that are involved in innovative activities. Thus, it identifies some fundamental structural conditions that contribute to define competencies, incentives and dynamic properties of the innovative process*" (Malerba, 2005, p.64).

Amongst the demographic and industrial organisation factors affected by the knowledge base are: (i) firms' survival rates (Audretsch and Mahmood, 1994); (ii) entry rates (Audretsch and Acs, 1994)[19]; (iii) market turbulence (Acs and Audretsch, 1990); (iv) output growth rates (Audretsch, 1995); and (v) levels of market concentration[20] (Geroski, 1995).

Following the seminal works of Schumpeter, Nelson and Winter (1982) and Winter (1984) define two basic technological regimes based on the knowledge base: an 'entrepreneurial regime', which due to the non-cumulativeness and universality of the knowledge base facilitates the entry of new firms,

[18] These underestimate small business innovation strategies (Freeman and Soete, 1997).
[19] The empirical evidence on entry, exit and market turbulence are not uncontroversial though (Marsili, 2001).
[20] Besides, inter-industry asymmetries in the degree of market concentration are highly significant and persistent over time (Geroski, 1994).

and a 'routinised regime' in which the cumulativeness of the knowledge base and its level of specificity create important entry barriers. Even though these resemble Schumpeter's Mark I and Mark II models, the market-structure is not exogenous anymore, but rather determined by the nature of the process of technological progress. Following Nelson and Winter (1982), a number of authors (Gort and Klepper, 1982; Levin *et al*., 1985; Cohen and Levin, 1989; and Audretsch, 1995) have investigated the role of other elements in the dynamics of market-structure and innovation. In general these have shown that the level of technological opportunities and appropriability conditions, in comparison to firm size and demand, are highly significant[21].

Malerba and Orsenigo (1990, 1993) and Breschi, Malerba and Orsenigo (2000) defined four main dimensions of the concept of technological regime: (i) the nature of the knowledge base upon which firms' innovative activities are based[22]; (ii) the appropriability conditions[23]; (iii) the cumulativeness conditions[24]; and (iv) the technological opportunities[25]. The latter expresses the level of productivity of the innovative effort or, as defined by Cohen and Levinthal (1990), the ease of obtaining innovative output *relatively* to the amount of resources devoted to innovative activities[26]. Much of the recent literature on the topic, as it will be discussed in the next section, seeks to identify specific technological paradigms based on these dimensions.

In a related approach, Marsili and Verspagen (2002) increased the concept of technological regime to other determinants, thus, defining five regime types. Likewise, a number of studies explore country-specific regimes: Italy (Sirilli and Evangelista, 1998; Evangelista, 1999), Sweden (Sellenthin and Hommen, 2002), Greece (Souitaris, 2002), Belgium (Veugelers and Cassiman, 1999), etc.

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[21] Econometric exercises were significantly improved with the use of proxies for the opportunity and appropriability conditions (Levin *et al*., 1985; Cohen and Levin, 1989).

[22] The literature usually defines the nature of the knowledge base through using binary characteristics: generic or specific, codified or tacit, simple or complex, independent or systemic.

[23] That is, the level of protection from imitators, which can occur via patents, process secrecy, know-how, design, and non-technical means.

[24] Which define the extent to which current innovative activity builds upon the experience and results obtained in the past.

[25] Technological opportunities can be further decomposed into their determinants, such as its variety, pervasiveness and sources (Cohen and Levinthal, 1990). These depend above all on the type of interactions firms establish with other agents in the sectoral system of innovation (Breshi, Malerba and Orsenigo, 2000).

[26] In general, opportunities are high in technologically advanced and emerging sectors, and low in traditional low-tech industries (Von Tunzelmann and Acha, 2005).

The endogeneity of the market-structure in the technological conditions is also highlighted in alternative approaches. Dosi's (1982, 1988) 'technological paradigm and trajectories approach', for instance, sees the sources of innovation variety as primarily determined by the technological characteristics. Likewise, Sutton's (1988) 'bounds approach' argues that the relationship between market-structure and innovation is constrained by the specificity of the technology in terms of the diversity of possible technological trajectories available to firms and the productivity of R&D investments along each trajectory.

1.2.3. Sectoral patterns of innovation

Provided that (i) 'industries differ significantly in the extent to which they can exploit the prevailing general natural trajectories, and that (ii) these differences influence the rise and fall of different industries and technologies' (Nelson and Winter, 1977: 59), this empirical branch of the Evolutionary school aims at defining patterns of innovation originating in sectoral differences in aspects such as sources of innovation, mechanisms of appropriability, the intensity and type of interactions established by firms[27].

The literature offers a great diversity of classifications or typologies of innovation based either on the indicators in hand, clustering methods and/or even the level of disaggregation of the database. Rosenberg (1982), for instance, focuses on innovation sources, Levin *et al*. (1987) define patterns of innovation based on appropriability conditions, Nelson (1993) on linkages with universities. Some other industry-specific aspects are assumed to have only a marginal impact. For instance, Cohen, Levin and Mowery (1987) and Geroski (1995) point out that demand conditions or the incentive provided by the dynamics of the demand[28] – measured by income elasticities, market growth and market size – seem not to have a significant influence on the pace of technological progress. Besides, static economies of scale (Acs and Audretsch, 1988; Geroski, 1995) and the level of unionisation of the labour market (Geroski, 1995) also present only marginal/null incentives to innovation.

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[27] The distinction between technological regime and the 'innovation patterns' approach can be subtle in most cases. Many authors consider both these lines in the same category, being the second only an emphasis on appropriability mechanisms (Malerba and Orsenigo, 1999). Castellacci (2006, 2009) call the latter by "technological trajectory" approach.

[28] As in the demand pull model (Schmookler, 1966).

Pavitt (1984), the most influential study in this stream, proposes an innovation taxonomy that emphasises the connections between (i) technological opportunities and sources of technology, (ii) users' needs, and (iii) appropriability mechanisms.

> "*Since patterns of innovation are cumulative, its technological trajectories are largely determined by what it has done in the past, in other words, by its principal activities. Different principal activities generate different technological trajectories. […] These different trajectories can in turn be explained by sectoral differences in three characteristics: sources of technology, users' needs, and means of appropriating benefits*" (Pavitt, 1984, p.353).

Investigating the characteristics of different sectors in Britain between 1945 and 1979, Pavitt identified four dominant technological trajectories or sectoral patterns of innovation, namely: (i) supplier dominated, (ii) scale intensive, (iii) specialised suppliers, and (iv) science-based industries.

Table 1.1 - Innovation classification by ISIC2 manufacturing industries

<table>
<tr><th>ISIC</th><th>Manufacturing sectors</th><th>Pavitt (1984)</th><th>Marsili (2001)</th><th>Castellacci (2009)</th><th>Industrial Sophistication (complexity)*</th></tr>
<tr><td>29</td><td>Machinery and equipment</td><td rowspan="2">Specialised suppliers</td><td rowspan="2">Product engineering</td><td rowspan="5">Advanced users-based</td><td>High</td></tr>
<tr><td>33</td><td>Medical and optical</td><td>High</td></tr>
<tr><td>31</td><td>Electrical</td><td rowspan="5">Science-based</td><td rowspan="3">Science-based</td><td>Medium-low</td></tr>
<tr><td>32</td><td>Radio and TV</td><td>Medium-high</td></tr>
<tr><td>30</td><td>Office and computing</td><td>Medium-high</td></tr>
<tr><td>24</td><td>Chemicals</td><td rowspan="2">Fundamental process</td><td rowspan="2">Systemic</td><td>Medium-low</td></tr>
<tr><td>23</td><td>Coke, petroleum, nuclear</td><td>Low</td></tr>
<tr><td>34</td><td>Motor vehicles</td><td rowspan="6">Scale intensive</td><td rowspan="2">Complex system</td><td rowspan="5">Investment intensive</td><td>Medium-high</td></tr>
<tr><td>35</td><td>Other-transport equipment</td><td>Medium-high</td></tr>
<tr><td>25</td><td>Rubber and plastics</td><td rowspan="2">Product engineering</td><td>Medium-low</td></tr>
<tr><td>28</td><td>Fabricated metals</td><td>High</td></tr>
<tr><td>27</td><td>Basic metals</td><td rowspan="11">Continuous process</td><td>Low</td></tr>
<tr><td>15</td><td>Food and beverages</td><td rowspan="9">Embodied diffusion</td><td>Medium-low</td></tr>
<tr><td>17</td><td>Textiles</td><td rowspan="8">Supplier dominated</td><td>Low</td></tr>
<tr><td>18</td><td>Wearing</td><td>Low</td></tr>
<tr><td>19</td><td>Leather and footwear</td><td>Low</td></tr>
<tr><td>20</td><td>Wood and related</td><td>Medium-low</td></tr>
<tr><td>21</td><td>Pulp and paper</td><td>Medium-high</td></tr>
<tr><td>22</td><td>Printing and publishing</td><td>High</td></tr>
<tr><td>26</td><td>Other non-metallic mineral</td><td>Medium-low</td></tr>
<tr><td>36</td><td>Furniture</td><td>Medium-low</td></tr>
</table>

* estimated by the author using data from UNIDO (See Chapter 7 and Appendix 1 for countries and product samples)
Source: author's own elaboration

Although Pavitt's taxonomy has been tremendously successful in empirical research, the recent publication of more comprehensive datasets on the innovative characteristics of firms[29], opened room for a series of refinements on the typology. Two interesting works in this direction are Marsili (2001) and Castellacci (2009). The first reinforces the interconnection between elements in the knowledge base with Pavitt's original variables, whereas the former adds the cross-country variability of systemic interactions between innovative firms and other actors in the sectoral system into the taxonomy. Table 1.1 shows how Pavitt, Marsili and Castellacci's typologies classify each ISIC 2-digit manufacturing sector.

In summary, the empirical studies in the stream have been prolific in providing the characterisation of the innovation process for a number of sectors. The approach also helped uncovering key factors affecting the process of innovation and its dynamics. The more recent literature, discussed in the next section, integrates systemic and multilevel elements to cope with the 'complexity' of the innovation process.

1.2.4. The systemic approach

Inspired on the Innovation System literature (Edquist, 1997), the most recent Evolutionary branch shares the emphasis on the knowledge and technological base with previous approaches, but stands out for highlighting also the role of a set of complex institutional and collective/interactive factors in the determination of the dynamics of the innovation process. The so called 'sectoral system approach' (Malerba, 2002, 2005) argues that firms are not the lone actors of the innovation process, which is best understood as the result of the interaction[30] between firms in related and complementary activities, and non-firm organisations, such as universities, research centres, etc[31].

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[29] The empirical nature of this literature makes it more reliant on the quality and comprehensiveness of the data on innovation than the technological regimes approach. A proper identification of the range of possible innovative strategies, their sources, objectives and outcomes is key for the proper conceptual distinction between different innovation patterns. Understanding the variety of ways with which the process of innovation occurs is fundamental, especially because of the limitations of usual measurements of innovation input (Patel and Pavitt, 1995).

[30] The interaction can occur through processes of communication, exchange, cooperation, competition, command, among others.

[31] The set of actors in the system includes, among others: Individuals (e.g. consumers, entrepreneurs, etc), firms (users, producers, suppliers) and organizations (universities, research centres, government, financial institutions, etc) at various levels of aggregation and with specific competences, organisational structures, goals and learning processes.

Accordingly, given the definition of a sector and its boundaries[32], a sectoral system of innovation can be seen as a set of heterogeneous agents carrying out market and non-market interactions for the creation, development and diffusion of new products (Malerba, 2005 p.65-66). Therefore, the variety of agents, the interactions established, and the institutions[33] that shape those interactions add up to the knowledge and technological base as determinants of the process of innovation and sectoral differentiation.

The emphasis on the agents and their interactions give to the sectoral system approach[34] a whole new set of tools to assess the process of innovation and its relationship with structural elements. In other words, the innovation systems approach embraces all the sectoral complexity to completely reshape the connections between the market-structure (which now includes networks, i.e., the links and relationships between a wide variety of agents, not only firms) and innovation. An important distinction concerns the role of agents in different levels of aggregation. Firms and collective of firms, for instance, offer different inputs to the system and their actions are likely to impact each other in multiple ways. The same is valid for all other agents in the system. Furthermore, unlike the previous approaches, there is a specific (or more pro-active) interest in the dynamics of the system. Since the sectoral system is seen as a "*collective emergent outcome of the interaction and co-evolution of its various elements*" (Malerba, 2005 p.68), the evolution of the knowledge and technological base, institutions and agents and their networks is central and brings about important reflections on the role of structural elements in the process of structural change itself, and not only in the shaping innovation patterns. Likewise, for acknowledging the systemic conditions of the innovation process, the approach delivers a clear link with market and performance elements, whereas much of the previous literature focuses on the innovation process only, leaving aside its economic consequences and growth impact.

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[32] A sector is defined as a set of activities sharing inputs and a common knowledge and technological base, and oriented to attend a specific (potential or existing) demand. Its boundaries can be dynamic, especially when links and complementarities with different sectors are big.

[33] These can be norms, routines, common habits, established practices, rules, laws, standards, etc, that may be formal or tacit and ranging from more binding, as law enforcement, to less binding, as the ones created by the interaction of agents, as contracts, for instance (Lundvall, 1993).

[34] In particular, the notion of sectoral systems of innovation complements other concepts such as national systems of innovation (Freeman, 1987; Lundvall, 1993), regional/local innovation systems (Cooke *et al*., 1997) and technological systems (Hughes, 1984).

1.2.5. Firm size and innovation variety: a critical summary of the empirical literature

The historical narrative in sections 1.2.1 to 1.2.4 points to the conclusion that the Evolutionary literature evolved from an exogenous view of the innovation process to an endogenous, multifaceted (systemic) and complex view of the phenomenon. More than new determinants for the process of firm and sector differentiation, an intricate set of self-reinforcing elements were embraced by the analysis, contributing to diluting the relevance of the market-structure for innovation, where conceptual and methodological problems add up to the criticism of the Schumpeterian hypothesis (Cohen, 1995).

The recent publication of comprehensive firm-level datasets on production and innovation strategies (e.g., the Community Innovation Survey - CIS), however, opened the possibility to reassess the importance of firm size to innovation and growth (Castellacci, 2009; Cáceres, Guzmán and Rekowski, 2011). The number of innovation strategies catalogued has vastly increased in the last decades, which contributed to a surge of studies focused on clustering the innovation strategies[35] (e.g. Evangelista and Mastrostefano, 2006; Cáceres, Guzmán and Rekowski, 2011). These have been showing that firm size interacts with sectoral elements in the determination of innovation and has a major role in the firm's decision to innovate as well as in the determination of some important types of innovation.

Take the disaggregated evidence in Table 1.2, where a number of innovation strategies are depicted along with the contribution of the country, sector and size to the variance of the variable across all units. Although Evangelista and Mastrostefano (2006), which originally published the study, found that size accounts for an average of 6% of the innovation variance when analysing 32 indicators of innovation, when the different dimensions of the innovation process are considered individually, the relevance of each elements vary significantly. Moreover, the residual, composed by firm-level aspects and interactions between the three factors presented, can account for as much as 90% of the variability of some innovation indicators, indicating that the sector cannot be seen as the sole determinant of innovation, as much of the recent Evolutionary literature suggest. In fact, this

[35] These are mainly interested in three aspects: (i) the identification and characterisation of innovation variety; (ii) clustering innovation strategies; and (iii) identifying and weighting the sources of innovation variety, which usually involves factor analysis, ANOVA and principal component methods to single out the most relevant innovation strategies and measure the influence of firm, sector and country elements in their determination and variability.

dissertation argues for a necessary reinterpretation of the role of firm size in sectoral innovation trajectories (this is further explored in Chapter 5).

Overall, sector and country together account for an average of 34%-50% of the variability of the 16 innovation indicators presented. Although firm size accounted for an average of 7%-12% of the variability of these indicators, it is the single most important aspects for the decision whether to innovate or not. Furthermore, it accounts for between 20% to 25% of the variability of (i) the percentage of firms actually innovating, (ii) with declared patenting activity and/or doing product and (iii) process innovation activities indicators, whereas 50%-62% is credited to firm-specific characteristics (measured by the residual). These make of the firm size a key determinant of cost-competitiveness strategies such as process innovation and imitation strategies.

Table 1.2 - Selected innovation dimensions and sources: variance decomposition

Indicators		**Total variance explained (R^2)**	**F**	**Variance explained by (share of R2)**			**Residual**
				Factor country	**Factor sector**	**Factor size**	
Innovation performance							
INNO	% of innovating firms on total firms	0.70	30.7	0.24	0.21	0.25	0.30
PAT	% of firms with at least a patent application	0.59	15.9	0.21	0.17	0.21	0.41
INMAR	% of firms introducing new products	0.49	14.5	0.09	0.24	0.16	0.51
RDEXP	R&D expenditures per employee	0.32	5.2	0.05	0.23	0.04	0.68
INEXP	Total innovation costs per employee	0.31	6.3	0.04	0.24	0.03	0.69
RDPER	% of R&D personnel on total employment	0.58	16.4	0.13	0.42	0.02	0.42
R^2 mean		**0.50**	**-**	**0.13**	**0.25**	**0.12**	**0.50**
Type of innovation activity and strategy							
INPCS	% of firms introducing process innovation	0.54	17.5	0.15	0.13	0.26	0.46
INPDT	% of firms introducing product innovation	0.72	38.3	0.25	0.27	0.20	0.28
RTR	Training expenditures/innovation costs (%)	0.19	2.8	0.13	0.05	0.01	0.81
RMAR	Marketing expenditures/innovation costs (%)	0.18	2.5	0.04	0.13	0.01	0.82
RID	Design expenditures/innovation costs (%)	0.09	1.1	0.04	0.05	0.00	0.91
R^2 mean		**0.34**	**-**	**0.12**	**0.13**	**0.10**	**0.66**
Technological linkages and contextual factors							
CO	% o firms with cooperation agreements	0.55	14.5	0.25	0.15	0.14	0.45
SSB	Scientific and technological institutions	0.60	13.5	0.42	0.10	0.09	0.40
SPAT	Patent disclosures	0.53	10.2	0.33	0.12	0.09	0.47
HORG	Organization rigidities within the enterprises	0.28	3.1	0.13	0.13	0.01	0.72
HPERS	Lack of qualified personnel	0.22	2.4	0.12	0.08	0.01	0.78
R^2 mean		**0.44**	**-**	**0.25**	**0.12**	**0.07**	**0.56**

Source: CIS database (adapted from Evangelista and Mastrostefano, 2006)

In another study, Cáceres, Guzman and Rekowski (2011)[36] reviewed a vast literature to select 19 innovation indexes based on common technological characteristics and innovation strategies[37]. They employed factor analysis to single out the main innovation strategies[38], namely: (i) training; (ii) R&D and collaboration; (iii) investment in new capital; (iv) patents; (v) internationalization; and (vi) imitation. Although their method and data suffer from a number of limitations, the study confirmed previous assumptions that R&D and patents account for only a small share of the firm-level innovation strategies. The authors found that the firm size accounted for 2 to 4 times the influence of the sector on R&D, collaboration strategies, internationalisation and imitation, whereas in the patents component its importance was comparable to that of sectors.

In summary, although the literature has evolved towards the acknowledgment of the endogeneity of innovation and market-structure in the sectoral regime[39] determined by the knowledge base, the more recent data on innovation suggests that the importance of firm size for innovation vary significantly across innovation dimensions. This suggests that the interaction between firm size and technological regimes can be more complex than the literature on innovation patterns argues, bearing the size a more active role in the process than merely conforming pre-defined sectoral patterns. Chapter 5 will propose a model that redeem the Schumpeterian hypothesis and give a key role for the firm size in technical change trajectories.

1.3. Inter-sectoral studies: hysteresis and patterns of specialisation

The meso-macro studies in the Evolutionary tradition are generally focused on understanding how hysteresis or path-dependent processes of innovation forge singular patterns of production and innovation across countries. Technological progress is described as an ordered process of accumulation of both interchangeable and specific capabilities that are selectively combined in the production of different goods and services. The interrelatedness of the productive process (plant, equipment, human and organizational capital, etc) "*demands that capital accumulated in the present*

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[36] The approach has a number of limitations: (i) The number of sectors limit the variability of the element. (ii) Much of variability found are due to the choice of indicators. (iii) The methods are poorly developed and the database is too restrictive.

[37] These were designed to measure the firm's level of commitment with each strategy. Finally, a questionnaire was applied to a sample of 293 small and medium enterprises in the region of Seville in Spain.

[38] These explain 60% of the data variance, where each was found to contribute with approximately 10% of the total variance.

[39] Scott (1984) found that the industry accounts for circa 32% of the variability in R&D intensity. Later, Cohen, Levin and Mowery (1987) pointed that the industry can account for as much as 50% of the variability in R&D. In a different perspective, testing the endogeneity of the market-structure and innovation process in the technological regime, Marsili (2001) verified that, on average, 63% of the variability in the firm size distribution is explained by sector-specific characteristics.

conform to technical and social standards inherited from past, unless more radical (non-marginal) changes in the production process are to be contemplated" (Setterfield, 2003, p.222). Besides, these interconnections are expected to increase with the scale of the economic activity, increasing the relevance of the lock-in phenomena in the determination of the equilibrium output and patterns of specialisation and transformation[40].

This section introduces the main ideas behind the meso-macro studies in this tradition. The focus is on the notion of 'structural sophistication' or 'economic complexification', which derives from the association between the productive structure and specific capabilities. The studies at this analytical level usually associate growth with the diversification of the productive structure. This idea is key for the explanation of the role of the inter-sectoral allocation on growth trajectories, which is further developed in Chapter 7.

1.3.1. From technology progress to structural change: capabilities and the productive structure

The meso macro-level studies in the Evolutionary tradition usually assume that for the production of any good a sector or country should possess a number of specific capabilities, where the latter are understood as assets or competences[41]. The usual assumption of homogeneous productive capabilities in economics eliminates any role for the productive structure and structural change in the growth process. Differentiating between these assets thus imply that for the production of each good, the productive unit (firm, sector, country) has to internalise different capabilities, which are reflected in the outcome of the production process. As a corollary, the capabilities internalised by an economy should be reflected in its productive structure. Moreover, the structural change process should cast light on the capabilities recently acquired[42].

[40] The Lock-in occurs when the system is doomed to follow a specific path, even if alternatives are arguable better. When specialised in a specific sector, with dedicated capital accumulated, even if the relative terms of exchange become highly favourable to other activities, the productive structure of the economy hardly change, due to the fact that the specialisation on the initial sector prompts high sunk costs, making the productive transformation prohibitive.

[41] Capabilities can be of static nature, as the knowledge necessary to produce a good, or dynamic, as the ability to make changes in the technical platform (learning capacity). The concept may not comprise only immaterial elements (skills, know-how, organizational abilities, institutions, for instance), but also embodied competences, as production inputs (raw materials, tools, machines, etc).

[42] That is, because different sets of capabilities are required in the production of each good, the good itself is indistinct from the capabilities it requires.

The Evolutionary theory proposes that there is an almost fixed order in which both the production process can be enlarged and the methods of production learnt. These are connected with the path of technological progress set by the capabilities internalised in the country, which determines the level of lock-in of the productive structure. Technological progress is thus an ordered process of accumulation of both interchangeable and specific capabilities that are selectively combined in the production of different goods and services.

In a recent work, Hidalgo *et al*. (2007) combines elements from Evolutionary, network theory and Structuralist approaches to show that economic development is a process of learning how to produce more sophisticated (complex) products[43]. Hausmann and Hidalgo (2011) estimated that, according to the level of disaggregation of the analysis, the total number of capabilities vary from 23 to 80[44]. These are 'embodied in the tacit knowledge of the individuals who comprise the firm's workforce' (Felipe *et al*., 2012 p.37). Some are interchangeable, but the lack of only one may result in a comparative disadvantage (Kremer, 1993). The hypothesis, broadly corroborated by the data, is that products of higher complexity are associated with higher levels of productivity. Sutton (2001, 2005) argues that capabilities are manifested as a quality-productivity combination. These, however, are not in a continuum, but rather in a window with a minimum threshold below which firms are excluded from the market of that product (Felipe *et al*., 2012).

These ideas are reflected in the product space theory developed by Hidalgo *et al*., (2007). This consists of an n-dimensional representation of all goods/sectors, where these are disposed in the space according to the similarity of their required capabilities. As expected, the link between high-complex products/sectors is much stronger than the link between these and primary products. The product space has shown that higher complexity products are in a much denser space than lower complexity products. An important conclusion is that the more diversified a country, the bigger the set of capabilities it has internalised.

Diversification is indeed an important aspect in this literature. Much of its importance stems from externalities trickling down from dynamic/transversal industries (as is the case of electronics) to other industries (Fagerberg and Verspagen, 1999). Another important argument is the increased

[43] The complexity of a product is a function of the required capabilities for its production, while the country's complexity is given by the number of capabilities locally available.
[44] See Chapter 7 for the estimation process.

versatility diversified economies display. Part of the literature advocates that diversification contributes to the structural change process, creating 'scope for technological progress'. Hausmann and Klinger (2006, p.1) argue that "*the assets and capabilities needed to produce one good are imperfect substitutes for those needed to produce other goods, but the degree of asset specificity varies widely. Given this, the speed of structural transformation will depend on the density of the product space near the area where each country has developed its comparative advantage*". Put simply, the more diversified an economy, the more flexible is its internal productive structure to produce new goods or even to make a shift towards more dynamic sectors. According to Salter (1960, p.9), "*a flexible structure of production is an important element in the high rate of productivity increase, for it allows an economy to rapidly redistribute its resources so as to take maximum advantage of changing patterns of technological progress*".

The connection between these ideas and studies on patterns of specialisation are obvious, especially when the influence of demand in the inter-sectoral allocation is highlighted. In the process of development, countries tend to expand their production towards products within the range of capabilities they already possess. Notwithstanding, 'non-homothetic' tastes give rise to entirely different compositions of demand and, therefore, different structures of production and employment, according to the particular levels of real per capita income. That is, increases in per capita income are not translated into a proportional increase of demand for different goods and services, due to Engel’s Law. Hence, changes in the composition of demand will also give rise, on the production side, to variations in the sectoral composition of the economy, forging distinct patterns of specialisation in the process of development.

1.3.2. Patterns of specialisation, diversification and growth: an empirical summary

One of the most celebrated corollaries of the principle of comparative advantages, whether from the Ricardian or Heckscher-Ohlin type, is that specialisation is the main source of productivity development (Dornbusch, Fisher and Samuelson, 1977). Such a prescription, however, goes sharply against the recent empirical evidence, which shows a clear (positive) correlation between productive diversification and economic development (Rodrik, 2006). The same idea is expressed in the related evidence, such as that rich countries are non-specialized (Imbs and Wacziarg, 2003) and that countries with export baskets less plugged to specific products grow faster (Hausmann, Pritchett and Rodrik, 2005).

Attempts to connect diversification (or specialisation) with growth are abundant in the empirical literature. Methodologically, these range from plain cross-country comparisons of historical data (Imbs and Wacziarg, 2003; Rodrik, 2006; Pagés, 2010) to less straightforward studies, where the focus is on complexities conformed by a diversified economic environment (Hausmann, Hwang and Rodrik, 2007; Hausmann and Hidalgo, 2011, Hidalgo and Hausmann, 2009). Measures of diversity range from simple concentration indexes, such as the traditional Hirschman (1964) index and the entropy index (Saviotti and Frenken, 2008), to the 'product space' and other complexity measures (Hidalgo *et al*., 2007; Hausmann and Klinger 2006; Hausmann *et al*., 2006).

Two direct attempts to associate growth with diversification are found in Hesse (2008) and Lederman and Maloney (2007) works. The first study, based on simple econometric evidence, contends that there is a positive relationship between diversification and growth dynamism, especially in developing countries. The second study suggests that there is a negative relationship between the concentration of exports – measured by a Herfindahl index of the share of natural resources in exports – and output growth, even though they found no evidence of a negative relation between the output growth rate and the abundance of natural resources[45].

Fagerberg (2000) also explores connection between productive structure and growth by regressing the productivity growth in manufacturing on the change in the share of the electrical machinery industry and other high tech sectors in total manufacturing employment. The measured impact of the relative specialisation in these sectors (especially electrical machinery) to total manufacturing productivity was positive and statistically significant. According to the author, a 1% increase in the sectoral workforce increases the growth rate about 0.5%.

In a more intricate study, Hausmann, Hwang and Rodrik (2007) evaluate the relationship between these variables in a model of 'discovery costs' for new products. According to the authors, the existence of externalities in the production of a new good influences the productive specialisation (or diversification), which impacts the growth rate of the product. Cross section and panel data methods were applied to two different samples to estimate the relationship between an indicator of export productivity and the per capita output growth rate. A positive relationship between the

[45] This led to the conclusion that it is the concentration of exports that is the element responsible for the negative relationship with the growth rate and not the concentration in natural resources. Similar results were found by them when evaluating an index of intra-industry trade.

variables was found for all different samples and estimation methods (even when control variables such as human capital, initial level of output, capital-labour ratio and an institutional index were included). This led the authors to conclude an unconditional relationship between productivity in the production of exportable due to specialisation and the rate of output growth.

Hausmann and Klinger (2006) and Hidalgo *et al*. (2007) addressed the subject assessing the relationship between the type of good exported and growth. Using the 'product space' methodology, the authors calculated the productive proximity of a set of goods, taken two by two. This proximity index was defined as the country's minimum probability to export a good given that it exports other goods. This was calculated as an index of revealed comparative advantage. The results highlight a positive relationship between the 'quality' of goods exported and the rate of output growth. Besides, more sophisticated goods were found to be located in a more concentrated and connected space, indicating that technology and skills required for the production of these goods have high dependency, while those less sophisticated were located in a more diffuse and disjointed space. Finally, when analysing the movement of countries within the product space, the authors concluded that they tend to develop comparative advantages in products that are closer in the product space. Countries specialised in products with more diffused sectors face a much steeper path to get insertion into the production of more connected goods.

The same idea of complexities pervading industrial activities is seem from another standpoint in Chenery and Watanabe (1958) and Deutsch and Syrquin (1986). After gathering evidence that the use of intermediates increase with output growth in the development process (also, the use of primary products as intermediates declines and the intermediates from services and industry rises), they concluded that this reflects an increase in the density of the input-output matrices (that is, the density of sectors complexity) and is an indicative of the dependence of industrial growth on a parallel growth of modern activities (Syrquin, 1988).

Hausmann and Hidalgo (2011) go even further in the study of complexities and their connections to growth. A explained in the previous section, products are assumed to be combinations of many non-tradable inputs (or capabilities) so that a country's ability to grow depends on the number of capabilities it has internalised. This is confirmed by calibration exercises, although the relationship between the number of capabilities and the number of products was found to be non-linear. More interestingly, contrary to what might have been expected from traditional theories of trade, "*poorly* *diversified countries make products that most other countries make, while highly diversified countries make those products plus the products that few other countries make*" (Ibid, p.3).

1.4. Concluding remarks

Even though the Evolutionary principles of innovation variety and path-dependence provide sufficient foundations for understanding the allocation problem in its multiple levels, the current paradigm in this literature cannot explain neither the misallocation literature findings at the intra-sectoral level[46], nor how the intra-sectoral and the inter-sectoral allocation problems relate to one another (Jones, 2011). It is argued that three important gaps need to be tackled before an answer is available. Firstly, the adoption of meso rather than micro foundations in the analysis of the growth process (Dopfer, Foster and Potts, 2004). Secondly, a re-signification of the role played by firm size in technological trajectories (Castellacci, 2003). Finally, the re-qualification of the role played by demand in the innovation and growth processes (Verspagen, 2002). This dissertation should address each of these limitations.

As it will be discussed in Chapter 5 and 6, the excessive focus on retrieving basic sectoral patterns of innovation resulted in a general overlook of what explains performance disparities across and within sectors. Based on the concept of technological regimes and trajectories (Malerba, 1995; Malerba and Orsenigo, 1999; Castellacci, 2006, 2009) and the seminal work of Nelson and Winter (1982), this dissertation proposes a complete reinterpretation of the role of the firm size in innovation trajectories and growth. The adoption of meso- instead of micro-foundations is shown to allow an analytical response and give a new role for size and market-structure in the process of growth. The approach explains also the importance of the intra-sectoral allocation to growth, responding to the misallocation problem.

The approach in Chapters 7 to 9 concerns the connections between the intra-sectoral and inter-sectoral allocation problems. As this dissertation proposes, the full understanding of the phenomena requires the acknowledgement of the role of demand requisites in the process of development, something hardly explored in the Evolutionary literature and greatly criticised in the Keynesian tradition. Conceived as a non-neoclassical theory of technical change (Dosi, 1982), the Evolutionary approach sees in the variegated, path-dependent, stochastic and complex process of innovation the

[46] Chapter 4 discusses the premises and results of the misallocation literature.

engine of growth. Understood as a supply-led process, this literature completely ignored the role of demand in the growth process until recently, when a few studies explored the feedbacks between demand and the process of technical change (Peneder, 2003; Castellacci, 2009; Dosi, Fagiolo and Roventini, 2010; Verspagen, 2002). This dissertation is contributory of this growing literature.

The next chapter explores the Kaldorian growth model and its representation of both demand and supply. As the rest of this dissertation will show, the key to understand growth is in the interplay between increasing returns to scale and demand constraints reflected in the structural composition of the economy. The complementarities between the Evolutionary and Kaldorian approaches both fulfil the limitations in each approach as well as make it possible to explain the multilevel allocation problem explored in Chapters 3 and 4.

2 Demand and Supply Requisites for Growth: The Kaldorian Perspective

2.1. Introduction

The acknowledgment of the importance of the dynamics of the supply-side to growth is perhaps the most important contribution of the Kaldorian school to the demand-led growth theory. Nevertheless, the implications of such a revolutionary perspective were not fully developed by this literature. In fact, the dynamics of the supply-side was reduced to a direct relationship between output growth and productivity growth: the Verdoorn law, which synthesises the nature of the process of technological progress in these models. Due to its simplicity and great empirical appeal, the law contributed to undermine a more balanced role for supply and demand in the determination of the equilibrium growth rate.

This chapter introduces the main Kaldorian principles and discusses the demand and supply representation in the Kaldorian growth models. The criticism of the 'indistinct nature' of technological progress (which hinders a more active role for the productive structure and the process of structural change in the Kaldorian growth framework) is developed in Chapter 8, where the short- and long-term models are reconciled and the parameters made endogenous.

The rest of the chapter is organised as follows. Section 2.2 introduces the Kaldorian technological progress function (i.e., Verdoorn's law), and the income elasticities of demand, which represent the supply and demand requisites in these models, respectively. Section 2.3 shows how each of these elements appears in two of the most influential Kaldorian growth models: the cumulative causation model (CCM) and the balance-of-payments constrained growth model (BPCG). The first is usually accepted as a short-term model whereas the second represent the long-term equilibrium. Section 2.4 concludes the chapter by discussing the summarising the approach and its limitations.

2.2. Demand and supply in the Kaldorian model

The discussion that succeeded the publication of Harrod's 'Essay in the Dynamic Theory' (1939) brought the controversy on the direction of the causality between capital accumulation and demand growth to the centre of growth theory. In the Neoclassical tradition, the accumulation of capital supplies the resources for the ensuing growth and the expansion of income. Technological progress, originally assumed exogenous, is the key element, being responsible for pushing the economy forward. In contrast, in the Keynesian tradition inaugurated by Harrod, growth is a demand-led process. According to this view, due to the role of expectations on investment decisions, it is unlikely that any investment expenditure would be carried out in case the aggregate demand is depressed. Changes in elements such as the level of credit, the external income and the distribution of income, however, can create demand, leading the process of growth.

Kaldor, as Keynes and Harrod, defended a demand-led approach of growth. This is expressed in the central role played by Hicks's super multiplier in the canonical Kaldorian growth model. A special emphasis is given by Kaldor (1970, 1972) to the role of exports, the most exogenous element of demand. The most distinctive characteristic of the Kaldorian model, however, is in the central role played by the supply-side such trajectories, contrasting with other Keynesian approaches. This is expressed in the cumulative causation mechanism envisaged by the author. Recovering Young's (1928) idea, Kaldor (1966) claimed that the singular characteristics of the demand for manufactures foster economies of scale in this sector. Consequently, growth becomes endogenous, dependent on the growth of manufacturing itself. Rather than passively accommodating demand pressures, supply recursively interacts with demand for the determination of the growth rate of equilibrium[47]. One should keep in mind that this implies an explicit role for the productive structure in the determination of growth rates, even though this implication is not fully developed in the Kaldorian literature.

The modern Kaldorian growth theory builds upon these aspects to explain growth trajectories at both the short- and long-terms. Empirically, the cumulative causation model (Dixon and Thirlwall, 1975; McCombie and Thirlwall, 1994) presents better results when explaining the short-term process of growth, when the cumulative causation mechanism based on Verdoorn's law is still the most significant force contributing for growth. In the long-term, the balance-of-payments constrained growth model (Thirlwall, 1979; Thirlwall and Dixon, 1979) presents a better adherence to the data. Differently from the first, in the BPCG model the balance-of-payments constraint binds,

[47] Kaldor was a severe critic of the neoclassical equilibrium approach. Dixon and Thirlwall (1975), however, chose to model Kaldor's view in an equilibrium framework with initial conditions (a 'weak' path-dependence mechanism).

preventing the mechanism of cumulative causation to continue affecting the equilibrium growth rate[48].

This section concerns the foundations of the parameters representing both demand and supply in these models: the Kaldorian function of technological progress and the income elasticities of demand, respectively. Central elements in the Kaldorian growth models (see section 2.3), both of these are also fundamental for the representation of the productive structure of an economy. Chapters 6 and 8 also explore the vast empirical evidence on their importance and determinants.

2.2.1. Technological progress function and Verdoorn's law

According to Kaldor (1972), the economic analysis should be based on history rather than equilibrium. His argument is built upon the notion of cumulative causation, where the growth process is endogenous and cumulative, determined by the past trajectory. This process is led by demand, in the form of exogenous forces that guide the process of investment and consumption in the economy (idea synthesized in Hicks' super multiplier). Notwithstanding, it is the supply-side that fulfils the special attribution of operating the recursive process that leads to the cumulative growth scheme.

Kaldor’s (1957) technological progress function summarises the technical dynamism of the economy. Although Kaldor never dispensed much time working on its determinants, technological progress was assumed to be determined by two different elements: (i) the disembodied technological progress (a), and (ii) the embodied technological progress (measured by the capital-labour ratio k_L $=k - l$). These represent the channels through which technological progress is generated. Formally:

$$q = a + \omega k_L \qquad (2.1)$$

where q is the productivity growth rate and ω a parameter. The distinction between embodied and disembodied elements derives from the author's idea that technological progress result either from learning-by-doing (a) or the development of new capital goods (k_L). Both a and k_L, however, are assumed to depend on the output expansion rate y.

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[48] In this model, there is no explicit consideration of the supply-side of the economy, which is only indirectly represented by the income elasticities in the demand functions for imports and exports.

$$a = \rho_1 + \lambda_1 y \tag{2.2}$$

$$k_L = \rho_2 + \lambda_2 y \tag{2.3}$$

Substituting (2.2) and (2.3) in (2.1):

$$q = \rho + \lambda y \tag{2.4}$$

with $\rho = (\rho_1 + \omega\rho_2)$ and $\lambda = (\lambda_1 + \omega\lambda_2)$.

Equation (2.4) is otherwise known as Verdoorn's law (or Kaldor's Second Law)[49]. Verdoorn's law synthesises Kaldor's ideas on the role played by demand in fostering technical change and productivity growth. Important to note that from (2.4) there is no arguable distinction between the growth of labour productivity, which is induced by the growth of the capital stock, and productivity growth, generated by the actual technological progress[50]. In fact, although extremely simple, the relationship resumes an important observation made by Kaldor that both the development of the actual productive forces as well as innovations require more capital per worker. Therefore, the speed at which a society can absorb and exploit new production technique finds limits on its ability to accumulate capital, which is determined by the product growth rate[51].

The key in the relationship between output growth (or income growth) and productivity growth is the level of increasing returns to scale that stems either from static[52], dynamic[53], internal[54] and/or

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[49] It is worth emphasising that Verdoorn's (1949) original coefficient differs significantly from the Verdoorn's coefficient derived from Kaldor's technological progress function.

[50] This means that if we take the neoclassical production function, it would not be possible to distinguish between movements along the curve (due to variations of k) of movement of the curve itself (due to variations of A – the exogenous element of technological progress).

[51] The recent literature tends to admit that a large portion of technological progress is specific to capital goods. If this is true, the capacity of underdeveloped countries to absorb foreign technological progress is connected to the availability of capital goods, which might be damaged by BOP constraints.

[52] Static returns to scale are the cost reductions that can be obtained at any time by increasing the level of production given the available level of output and technology.

[53] Dynamic returns to scale are the cost reductions that can be obtained over time through the technological progress that results from increasing the level of production.

[54] Internal returns of scale are the cost reductions or productivity gains that result from increasing the scale of production of a particular firm.

external[55] sources. Even though his definition encompasses all these types, Kaldor stresses the particular importance of dynamic returns to scale. A positive estimate for λ implies increasing returns. On the other hand, if λ is not statistically different from zero, it is the case of constant returns to scale.

There is considerable discussion about the empirical relevance of the law. Verdoorn (1949) was the first to provide an estimate of the relationship. Using a sample of 13 OECD countries, he found a coefficient of 0.573, confirming the existence of increasing returns to scale. Kaldor (1966) adopted a different specification of the law and estimated it for manufacturing and non-manufacturing activities[56]. The estimate was positive, attesting increasing returns in manufacturing activities, while constant or decreasing returns was found for the non-manufacturing sector. The economy-wide estimate was around 0.5.

Following the seminal estimates of Verdoorn and Kaldor, a number of studies implemented improvements in the law, adding new dimensions such as the technology gap and innovations, in order to control for technological diffusion (León-Ledesma, 2002). In a criticism, Rowthorn (1975) tested the inverse relationship, finding no significant results for the [inverse] law.

The empirical literature on Verdoorn's law is vast. The estimates comprise different unit samples, which may include developed and developing countries, different sectoral aggregations, or even regional data. Also, a number of econometric techniques have all been applied[57]. Apart from Rowthorn's (1975) inverse relationship criticism, and the discussion around the static and dynamic versions of the law, the estimates tend to return a coefficient typically around 0.5, indicating that the hypothesis of increasing returns is empirically consistent (León-Ledesma, 2002; Angeriz, McCombie and Roberts, 2008). Chapter 6 present more detail on the empirical literature on the law.

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[55] External returns to scale are the cost reductions in the production of a particular firm that result from the growth of the firm's sector or of the rest of the economy.
[56] Kaldor's sample comprised 12 OECD countries in the period 1953-64.
[57] The concern with spurious estimations led the literature to adopt a number of techniques, instruments and controls. These include cross-country analysis (McCombie and de Ridder, 1983; León-Ledesma, 2002), time-series methods (McCombie and de Ridder, 1983; Harris and Liu, 1999; Millemaci and Ofria, 2014), and regional and/or multilevel estimations in cross-sections and panels (McCombie and de Ridder, 1984; Bernat, 1996; Fingleton and McCombie, 1998; León-Ledesma, 2000; Hansen and Zhang, 1996; Britto, 2008; Angeriz, McCombie and Roberts, 2008).

2.2.2. Demand Elasticities

The discussion on the role of demand on growth requires a comprehension of how consumption patterns are determined. Pasinetti's (1993, p.39) seminal investigation on the subject reached three conclusions: (i) increases in income per capita tend not to be spent proportionally by consumers in the various goods, but rather to move progressively towards less essential goods; (ii) besides income and price changes, the individual consumption bask*et al*so changes due to the introduction of new goods and services in the market; (iii) there is no good for which the individual consumption can increase indefinitely, even though the saturation level may diverge for each product and for different levels of per capita income. In summary, consumption patterns and, thus, demand patterns depend not only, but especially on the characteristics of the good (level of essentiality and substitutability), its price, and per capita income level.

Because of the level of simplification of the aggregate demand function, which comprises only prices and income, both price and income elasticities of demand should also reflect the nature of the products produced, omitted in the representation. For instance, one should expect that a country with high income-elasticity for its products to produce relatively less of subsistence goods and more of high-tech (superfluous) products. Indeed, Gouvêa and Lima (2010) and Romero, Silveira and Jayme Jr. (2011) showed that the income elasticity may reflect the level of technology of the production, concluding that countries specialised in high-tech products display higher income elasticities compared to the ones specialised in primary and low-tech products. It should be noted that this is the same to say that demand elasticities (in special, income elasticities) reflect the country's productive structure, or the level of development of the supply-side of the economy. Hence, changes in the income elasticities should reflect changes in the sectoral composition of the economy (due to idiosyncratic trajectories of demand and technological progress in each sector).

The role of demand elasticities as indicators of the product competitiveness was already highlighted in the seminal work of Dixon and Thirlwall (1975), even though the authors chose to keep these as exogenous parameters. Perhaps because of their scepticism regarding relative prices policies[58], this choice freed the income elasticities to be exogenously influenced by trade policies, being an important element for explaining regional growth disparities:

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[58] Neither devaluation, nor wage subsidies, were supposed to have a permanent effect on the rate of change of the exchange rate or money wages, only on the level of the exchange rate or money wages (what they called by an once-for-all change).

> *"We believe the income elasticity of demand for exports to be a particularly important parameter at both the national and regional level. Regional policy for stimulating regional growth could usefully direct its attention to identifying activities with a high income elasticity of demand and encouraging these to locate in depressed regions by policies of capital incentives and labour subsidies"* (Ibid, p. 212).

The exogeneity of the income elasticity also featured in the second generation of Kaldorian models (Thirlwall, 1979). However, because of the absence of the endogenous element of technological progress, alongside with the representation of the demand constraints, the parameter ended up representing the supply-side in the model (where the mechanism of path-dependence is manifested). Hence becoming responsible for growth disparities across countries and, ultimately, for the actual long-term equilibrium growth rate (Thirlwall's law). This is further explored in the next section, where two of the most important Kaldorian growth models are introduced.

2.3. The Kaldorian growth model

The contemporary Kaldorian growth framework can be separated in at least three distinct strands: (i) the cumulative causation model, which presents better empirical fit in short-term analyses; (ii) the balance-of-payments-constrained model, which is a long-term model; and (iii) the two-sector 'North-South' models, which explore Kaldor's emphasis on the role of manufacturing in growth trajectories. This section introduces the first two, which constitute the vast majority of studies in the literature. The approach taken emphasises the capacity of the one-sector Kaldorian representation to depict the interaction between demand and supply in growth trajectories[59].

2.3.1. The cumulative causation model: medium-term growth

The foundations of the seminal first-generation Kaldorian growth model are found in Kaldor (1970). Kaldor's verbal model comprises a system with two separated regions producing two different goods: manufacturing and agriculture. Once trade is set between the regions, the one with comparative advantages in manufacturing will also present more favourable terms in the agricultural good, leading to a contraction of the industrial sector in the second region without any compensation in the form of increased agricultural output (Dixon and Thirlwall, 1975:202). The key element behind this phenomenon was the idea of increasing returns to scale, which is associated

[59] In order to compare these approaches and their results, some modifications in relation to their canonical representation are implemented.

with the industrial production, according to the author. Although verbal, his description shaped the way the Post-Keynesianism model the growth process.

Pursuing a formal representation of this model, Dixon and Thirlwall (1975) chose to focus on one individual region and set the interregional growth differences in terms of the parameters of the model. The stability or divergence are, hence, assumed in relation to the region's own equilibrium growth rate. A partial equilibrium approach is adopted, meaning that each region is considered in isolation from all others and no interregional relationships are explicitly considered, but implicitly by the Verdoorn effect.

Kaldor's argument was greatly influenced by Hick's view that the long-run growth rate of output is determined by the autonomous demand. In sum, Hick's super-multiplier establishes that, under certain conditions, the growth rates of both consumption and induced investment follow the rate of change of the autonomous demand. It was Kaldor's contention, however, that in a regional context, the foremost autonomous factor should be the demand for exports. As a consequence, the Kaldorian studies have traditionally emphasised the importance of the external world in the determination of the growth rate.

This section presents a more general version of the canonical circular-causation model developed by Dixon and Thirlwall (1975), where both demand for exports and domestic spending are assumed to determine the income growth rate[60]. Assume thus that the aggregate demand (national income), Y, grows at a rate determined by the weighted average rate of growth of demand for exports and domestic spending, multiplied by the Keynesian multiplier (α).

$$y = \alpha(\omega_d d + \omega_x x) \tag{2.5}$$

where lowercase letters represent the rate of change of the variables (differences in natural logarithms). d is the growth rate of domestic spending, x the growth rate of exports, and ω_d and ω_x and the proportions of domestic spending and exports, respectively, in total demand.

[60] This equation was introduced in Setterfield and Cornwall (2002) and was also adopted by Blecker (2009).

The demand for exports (X) is specified as a constant-elasticity-function (CES) of the real exchange rate (EP^*/P) and foreign income (Z):

$$x = \eta(p_d - p_f - e) + \varepsilon z \tag{2.6}$$

Where p_d and p_f represent the rates of change in the levels of domestic and foreign prices, respectively. $\eta < 0$ is the price elasticity of demand for exports, and $\varepsilon > 0$ the income elasticity of demand for exports. The relation $(p_d - p_f - e)$ represents the rate of change of the domestic currency.

Although the foreign inflation (p_f) is exogenously determined (small country assumption), the domestic inflation is influenced by changes in the costs of labour and the gross profit mark-up:

$$p_d = \tau + w - q \tag{2.7}$$

Where τ is the rate of change of the mark-up on the cost of the work unit, w is the rate of wage inflation, and q the growth rate of labour productivity. For simplicity, $\tau = 0$, i.e., the rate of mark-up does not vary with changes in non-working costs (it would have a negative effect if not assumed null). Finally, productivity growth is endogenous as given in Equation (2.4).

If there is no 'excessive' cumulative causation, which would result in an explosive system, the combination of equations (2.4) to (2.7) renders a unique and stable equilibrium given by Equation (2.8)[61]. Algebraically, the condition[62] is that $1/\lambda > \alpha\omega_x\eta$ or $\alpha\lambda\omega_x\eta < 1$.

$$y_E = \frac{\alpha[\omega_d d + \omega_x(\eta(w - p_f - e) + \varepsilon z)] + \alpha\omega_x\eta\rho}{1 - \alpha\lambda\omega_x\eta} \tag{2.8}$$

Assuming that $\eta < 0$, the growth rate is shown to vary positively with d, ε, ρ, z, e, p_f, and λ, and negatively with w[63]. Regional differences in the growth rate are explained by differences in the

[61] The mere existence of cumulative causation is not sufficient to create a disequilibrium situation in the long run. Contrary to the expectations, the extreme cases, where αλω_x η≥1, are not commonly found.

[62] In the notation yet to be introduced, the condition is that the inclination of the PR line should be steeper than for the DR line.

[63] τ would also have a negative contribution if not assumed as null.

parameters of the model or in the Verdoorn coefficient (λ), which will also contribute to the expansion of these discrepancies. If, for simplification purposes, one assume that e, p_f, w e z are all exogenously determined, then the regional differences are exclusively determined by the nature of the products produced, which are synthesised in the structural parameters (λ, ρ, η, ε, and d). Indeed, "*from this analysis, it would appear that the message of Kaldor's model is that raising a region's growth rate is fundamentally a question of making regions more 'competitive' and/or altering the industrial structure so that goods are produced with higher income elasticities of demand and higher Verdoorn coefficients attached to them*" (Dixon and Thirlwall, 1975 p.210). Accordingly, "*regional policy for stimulating regional growth could usefully direct its attention to identifying activities with a high income elasticity of demand and encouraging these to locate in depressed regions by policies of capital incentives and labour subsidies*" (Dixon and Thirlwall, 1975 p.212).

In order to emphasise the interaction between demand and supply elements in the canonical Kaldorian model, one can assume the existence of two regimes that interact with each other in the equilibrium determination[64]. The first, given by demand conditions, represent the actual growth. The second represents the potential growth and is given by the supply conditions. Equations (2.5) to (2.7) can thus be combined to generate what Setterfield and Cornwall (2002) called by 'demand regime' (DR)[65]:

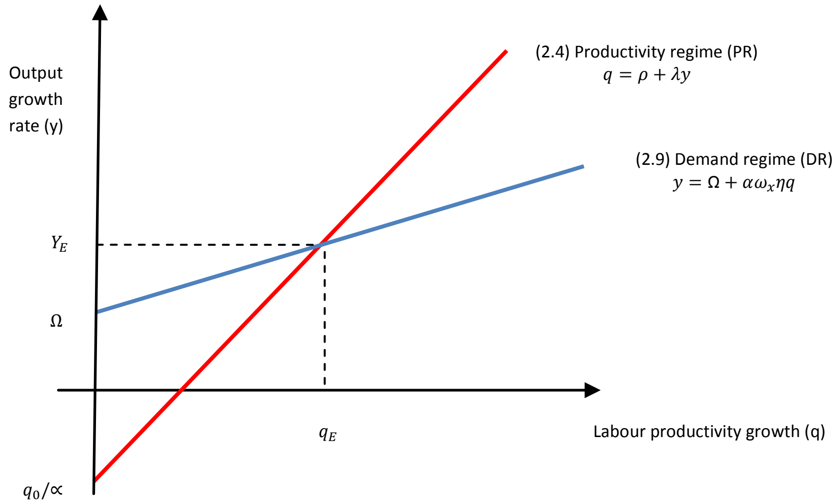
$$y = \Omega + \alpha\omega_x\eta\rho \qquad (2.9)$$

where $\Omega = \alpha[\omega_a d + \omega_x(\eta(w - p_f - e) + \varepsilon z)]$ and d, e, p_f, w e z are all treated as constants. Meanwhile, Verdoorn's equation (2.4) represents the supply dynamics (i.e., the technological progress function) and is called by 'productivity regime' (PR).

[64] C.f. Cornwall (1976), Setterfield and Cornwall (2002), Setterfield (2002) and Blecker (2009).

[65] The version presented here is an adaptation of the relationship of Blecker (2009). In the original model, the exchange rate and wages are omitted. Furthermore, the level of foreign price is determined via symmetric equations of mark-up and Verdoorn Law for the external sector.

Figure 2.1 - Demand and Supply equilibrium in the canonical Kaldorian framework



Source: adapted from Blecker (2009)

These form a system of two linear equations with two endogenous variables (output and productivity growth rates), with all the remaining variables being exogenously determined. Figure 2.1 illustrates the behaviour of the system. Looking at the supply-side of the economy, an exogenous shock that increases the rate of productivity growth (e.g., R&D subsidy) would raise ρ and move PR down and to the right. In such a case, the growth rate of equilibrium y_E would be raised. Accordingly, the higher the Verdoorn coefficient, the higher the equilibrium growth rate will be. On the demand-side of the economy, any event that stimulates a further expansion of the internal demand growth rate (d)[66] and/or exports growth rate (x) would make the inclination of DR steeper, increasing the rate of growth.

The over-simplification of the supply-side representation is an important source of criticism of the CCM growth model. It says nothing in a context with heterogeneous sectors, where increasing returns are only found in specific sectors. The model is also criticised for its possible explosive results. Another important issue is the sustainability of the equilibrium growth rate in the long-term. According to Setterfield (2013, p.22) "*it is unlikely that steady-state, demand-led growth will always be automatically accommodated by the supply-side. The conclusion reached is that attention must, therefore, be paid to the possible emergence of supply constraints on growth*". The same is defended by Cornwall (1972), Palley (2003), Setterfield (2006), among others. León-Ledesma (2002) and

[66] Given the nature of the model, the demand stimulus raises productivity of tradable goods, thus increasing the degree of national competitiveness and hence exports.

Blecker (2009) argues that the cumulative causation model presents a good description of the short and medium-term equilibrium, but not in the long-term, where some adjustments are necessary.

2.3.2. The balance-of-payments constrained growth model: the long-term equilibrium

The seeds for the next generation of Kaldorian growth models were already present in Dixon and Thirlwall's (1975) seminal paper. According to the authors, "at *the national level, a built-in balance-of-payments constraint would make the model more realistic*" (Ibid, p.213), reducing its tendency to over-predict the growth at the long-term (this was the case for the UK in their estimation). The basic flaw of the cumulative causation model is that "*no consideration is given to the possibility that the rate of growth of income determined by the model may generate a rate of growth of imports in excess of the rate of growth of exports, thereby imposing a constraint on the export-led growth rate if balance-of-payments equilibrium must be preserved*" (Thirlwall and Dixon, 1979, p.173).

Thirlwall's (1979) BPCG model depends on three simple equations: the demand for exports already present in the CCM (2.6), a function of demand for imports (2.10), and a balance-of-payments equilibrium condition (2.11):

$$m = \psi\left(p_f + e - p_d\right) + \pi y \qquad \textit{(2.10)}$$

$$m + p_f + e = p_d + x \qquad \textit{(2.11)}$$

Where m denotes the imports growth rate, $\psi < 0$ is the price elasticity of the demand for imports, and π is the income elasticity for imports. Solving the system of equations, we obtain the growth rate consistent with the long-term equilibrium of the BP, also known as Thirlwall's law:

$$y_{BP} = \frac{(1+\eta+\psi)\left(p_d - p_f - e\right) + \varepsilon z}{\pi} \qquad \textit{(2.12)}$$

It follows from (2.12) that:

(i) If the Marshall-Lerner condition holds $(\eta + \psi = -1)$[67], price effects have no effect on the equilibrium growth rate.

[67] The Marshall-Lerner condition is referred to as the technical reason why currency depreciations might not necessarily cause balance-of-payments improvements. For a currency devaluation to have a positive impact on

(ii) The same occurs if the purchasing power parity (PPP) holds (i.e., $p_d - p_f - e = 0$)[68].

(iii) The higher the world income growth rate the greater the equilibrium growth rate.

(iv) The higher the income elasticity of demand for imports (π), the lower the equilibrium growth rate.

The canonical BPCG model presented above has received a number of extensions[69]. Thirlwall and Hussain (1982), for instance, proposed the addition of capital inflows/outflows in the equilibrium equation, since the growth of net financial inflows can relax the BP constraint[70]. Moreno-Brid (1998) argues that the current account balance (which must be equal to the net financial inflows) needs to be a constant share of GDP in the long run[71].

The simplified specification of Thirlwall's Law requires that both (i) the current account is balanced in the long run, i.e., there is no growth of capital flows capable of indefinitely financing the overseas debt of countries with current account deficits; and that (ii) there are no changes in relative prices in the long term, i.e., it assumes either the elasticity pessimism[72] or the validity of PPP[73], such that relative prices between domestic and foreign goods do not change[74].

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the trade balance, the sum of the price elasticity of exports and imports (in absolute value) must be greater than 1. The so-called elasticity pessimism consists in assuming that $\eta + \psi = -1$.

[68] A depreciation of the exchange rate ($e > 0$) only increases the equilibrium growth rate if ($\eta + \psi < -1$).

[69] Although important, the empirical evidence show that the impact of these components is only secondary compared to the role of elasticities in the equilibrium growth rate. This occurs because countries cannot finance deficits in the BP indefinitely.

[70] The BP equilibrium equation is then given by:

$$P_d X + F = P_f ME$$

Where F represents the financial flows. Resulting in the following equilibrium growth rate:

$$y^*_{BOP} = [\theta \varepsilon Z + (1-\theta)(f - P_d)]/\pi$$

where θ is the share of exports in total receipts $(X + F)$.

[71] In this case, the balance-of-payments equilibrium condition is given by:

$$P_d X - F - R = P_f ME$$

Resulting in the following equilibrium growth rate:

$$y^{**}_{BOP} = [\theta_1 \varepsilon Z + \theta_2 r]/[\pi - (1 - \theta_1 - \theta_2)]$$

Where r and f are the growth rates of interest payments and capital flows, respectively, and $\theta_1 = X/P_f ME$ and $\theta_2 = R/P_f ME$.

[72] Neglecting relative price effects is controversial. If on one hand Alonso and Garcimartín (1998) were categorical in suggesting the validity of pessimism elasticities for most industrialised countries, Razmi (2005), among others, found no empirical evidence against the Marshall-Lerner condition for many countries.

[73] The empirical evidence on the validity of the PPP concerning the long term is also controversial and highly sensitive to currencies, indices, time periods and econometric methods (Rogoff, 1996). Moreover, it is far from a consensus that the long run equilibrium of the exchange rate needs to be constant.

[74] Thirlwall and Hussain (1982) accept that changes in export prices (which, in the model, are the same as domestic prices) can be significant for developing countries, but only insofar as they affect the real value of inputs' net financial measures in domestic currency, and not due to cumulative causation (which is implicitly

The latter is essential to exclude the possibility circular and cumulative causation in the model as, in this case, any productivity gains would be offset by both the appreciation of the exchange rate as by an increase in domestic prices[75]. That is, the increase in productivity growth leads to an increase in nominal wages and, hence, real wages growth. There is no change to the growth of domestic prices. Hence Pd=w–q and 0 =Δw-Δq. Real wages grow by Δw-Δpd=Δw. The gains in productivity are all passed on in the form of higher wages.

Henceforth, (2.12) can be simplified to (2.13-1) or (2.13-2). Both illustrate the maximum growth rate compatible with the balance-of-payments equilibrium in the long term.

$$y_{BP} = \frac{\varepsilon}{\pi} z \qquad \textit{(2.13-1)}$$

$$y_{BP} = \frac{x}{\pi} \qquad \textit{(2.13-2)}$$

It follows from (2.13-1)-(2.13-2) that a higher growth rate is only feasible by changing the income elasticities of demand for exports and imports (an increase and a decrease, respectively). This remarkable result highlights the importance of income elasticities (i.e., non-price competitiveness or production structure) in the determination of the product growth rate[76].

It is clear that the balance-of-payments constraint does not eliminate the importance of the growth of exports in the determination of output growth in the long-run. An increase in exports permit the increase of imports without the risk of chronic imbalances in the balance-of-payments. Nevertheless, Thirlwall and Dixon (1979) showed that under certain assumptions, the mechanism of cumulative causation might fail[77] and the equilibrium growth rate is capped to a level that is consistent with balance-of-payments equilibrium invalidating the approach in the CCM.

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excluded by the assumption of the PPP and even less are disregarded as of importance in developing countries because, historically, these are specialised in primary products).

[75] The PPP assumes the law of one price which implies large price elasticities. The model assumes that there is inflationary feedback from a devaluation that subsequently raises domestic prices proportionately.

[76] Empirically, a growing number of studies have been corroborating the BPCG theory hypothesis. McCombie and Thirlwall (1994) And Thirlwall (2011) provide a broad review of the empirical studies on Thirlwall's law.

[77] The Dixon-Thirlwall model shows under plausible assumptions of the parameters of the model, the cumulative causation model will lead to a growth rate starting from an initial level of income to converge to an equilibrium rate of growth – there cannot be explosive growth. But these equilibrium growth rates differ between regions and countries depending upon the parameters of the model.

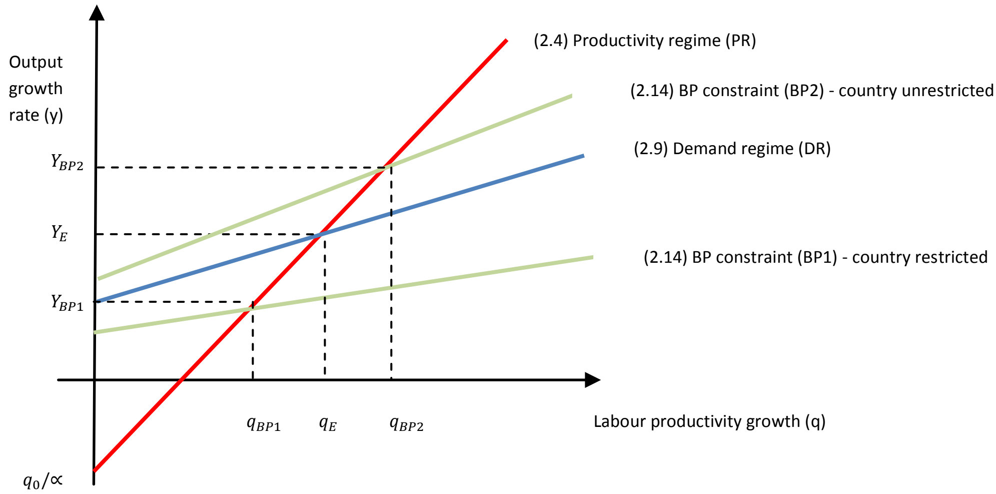
To have an idea of the impact of a balance-of-payments constraint over an economy operating with increasing returns to scale, simply plug (2.4) and (2.7) into the BPCG system of equations. This will result in the following general expression for the balance-of-payments constrained growth rate:

$$y_{BP} = \frac{(1+\eta+\psi)\left(w-\rho-p_f-e\right)+\varepsilon z}{\pi+\lambda(1+\eta+\psi)} \tag{2.14}$$

Equation (2.14) tells us that both ρ and λ help relaxing the BP constraint. The first directly and the second by increasing the multiplier, as $(1+\eta+\psi)<0$. Note, however, that in case the Marshall-Lerner condition just holds or, instead, the growth of wage rate equals the rate of productivity growth, then Equation (2.14) collapses to Thirlwall's law. That is, all the cumulative effect brought about by the Verdoorn coefficient is ruled out of the model, as it only enters the model through the price equation. This was the reason Thirlwall (1979) chose not to include this element in the original system of equation.

Consider that the relative prices still affect the economy in the long-term. The demand regime equation (DR) for the BPCG model can be obtained by inserting the price equation (2.7) into (2.12). If e and w are exogenously given, then y is only a function of q. As long as the Marshall-Lerner condition holds and PPP does not, the DR equation is upward sloping. In case PPP holds, but the Marshall-Lerner condition is violated, it would turn horizontal. Plotting the solution in the same $y-q$ graph against both the PR and the DR derived from the canonical Kaldorian model, one can see that the BP constraint results in an equilibrium growth rate lower than expected in case of no external constraints (or if the imbalance can be offset by financial flows). If the BP constraint is yet to be reached, the actual equilibrium growth rate is given by the equilibrium of the canonical model. Figure 2.2 illustrates both of these cases.

__Figure 2.2 - Demand and Supply equilibrium in the Kaldorian framework__



Source: author's own elaboration

In summary, the model asserts that a country experiencing a virtuous cycle of demand-led growth (Y_E) in the short-term will eventually be forced to adjust to the lower Y_{BP} growth rate, where the balance-of-payments is in equilibrium. The adjustment will probably be due to either (i) a reduction of domestic spending[78], which will lower the intercept in DR (Ω); and/or (ii) a relative price adjustment, which reduces the DR intercept (Ω)[79]. Similar considerations would apply in the opposite case depicted by the BP curve for a country that has no restrictions by the balance-of-payments (Y_{BP}> Y_E). Either the domestic demand will rise to accommodate the pressure, or there will be an exchange-rate depreciation (Blecker, 2009).

2.4. Concluding remarks

This chapter reviewed the Kaldorian contributions to growth theory, with emphasis on the interplay between demand and supply in the determination of growth. The first part introduced the structural parameters of the Kaldorian growth model: the Verdoorn coefficient and the income elasticities, which represent supply and demand requirements, respectively. Two of the most important models in the tradition, the cumulative causation model and the BPCG model were then introduced and their implications assessed in light of changes in the supply and demand regimes.

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[78] Which can result whether from a contractionary policy or from a private sector spending constraint, which can be induced by the increase in the interest rates due to the rising debt.
[79] Whether this is a stable adjustment depends on how price effects are assumed in the model. Examples are: an increase in the nominal wage growth rate or a currency appreciation.

The acknowledgment of the importance of both demand and supply in growth trajectories makes of the Kaldorian approach a special line of research[80], capable of interacting with approaches in the wide spectrum of economics. The approach has though a few important limitations: Firstly, the 'indistinct nature' of the technological progress induced by the Verdoorn law, which contributes to minimise the role played by the productive structure and structural change process in the growth process. Secondly, the lack of foundations for both income elasticities and Verdoorn's coefficient undermines extrapolations and the prescription of economic policies derived from these models (King, 2010).

Chapter 8 will show that a simple requalification of the inputs (material bases of the economy), in line with the Evolutionary concepts discussed in Chapter 1, can help reconciling the implications of the Kaldorian theory with modern supply-side approaches. Such an approach enables the emergence of supply constraints in the equilibrium growth rate, determined by the singular technological paths given by the productive specialisation. This is shown to explain distinct patterns of specialisation worldwide. Chapters 6 and 8 also present important evidence on the foundations of both demand elasticities and Verdoorn's law, contributing to fill these gaps in the theory.

[80] Even though much of the effort in this dissertation is to propose improve the supply side representation in the Kaldorian growth model, the interplay between demand and supply can also be seen through the endogeneity of factor supplies (see León-Ledesma and Thirlwall, 2002).

3. Inter-sectoral reallocation and growth: empirical investigation

3.1. Introduction

The so-called 'allocation problem' originates in divergences in either the technology of production and/or demand for products of different firms and sectors. The competitive advantages ensued by these heterogeneities are ultimately translated into divergent trajectories of productivity and distinct incentives to firms and sectors to invest and grow. Accordingly, the (re)distribution of factors across these heterogeneous units is a key element in the determination of growth at both short- and long-terms (Maddison, 1987).

At a macroeconomic analytical level, Fisher (1939) and Clark (1940) were the first to bring together the notions of 'accumulation of resources' and 'sectoral heterogeneity' to explain the modern phenomenon of growth (Syrquin, 1988). This idea was formalised in Lewis's (1954) dual-economy model. The evidence on the secular process of industrial transformation, where labour fled from agriculture (a low productivity sector) to high-productivity activities such as manufacturing and special services contributed to reinforce the importance of the sectoral composition and structural change process to growth.

Notwithstanding Kuznets' (1956-73) and Kaldor's (1966, 1970, 1985) stylised facts of growth highlight the distinctive role of manufacturing and the structural change process to growth, much of the empirical literature beginning in the decade of 1980 points to a negligible impact of these structural heterogeneities in growth trajectories (Fagerberg, 2000). According to these studies, the productivity gains originated in the secular process of industrial transformation have been depleted by the progressive process of equalisation of returns across manufacturing and agriculture sectors (Dollar and Wolff, 1988; Timmer and Szirmai, 2000).

This chapter argues that this literature failed to provide evidence on the importance of the structural change to growth for a misleading focus on the inter-industry reallocation process, whereas in modern-industrialised economies, the structural heterogeneity is much higher within these industries and not across them. The evidence in the literature suggests that this is especially important in the manufacturing sector, where a profound process of diversification is in course

(Lucas, 1993; Fagerberg, 2000)[81]. Apart from the seminal work of Salter (1960), only a few studies (Fagerberg, 2000; Timmer and Szirmai, 2000; Nelson and Pack, 1999) have emphasised the intra-manufacturing allocation problem. Even these, however, adopt a highly-aggregative sectoral breakdown. As this chapter will show, this influences directly on the results of productivity decomposition exercises.

This chapter analyses the relationship between structural change and productivity growth in manufacturing branches of 42 economies in the period comprehended between 1990 and 2009[82]. Different comparative methods, growth accounting and econometric exercises are adopted with the aim of both characterising the process of labour reallocation across manufacturing branches, and measuring its relative importance for growth. The approach seeks to characterise the level of productive heterogeneities in the manufacturing sector worldwide and the importance of labour reallocation for growth at the meso-macro analytical level, furnishing empirical justification for studying the inter-sectoral allocation problem. In total, 125 industrial sectors are covered in the analysis, providing an actual and much more detailed picture of the relationship between sectoral allocation and growth than any previous study.

The rest of the chapter is organised as follows. Section 3.2 reviews the empirical literature on growth accounting and structural change. The empirical intricacies are discussed and the perspective of the study justified. Section 3.3 presents an exhaustive exploratory analysis of the data. As in Kuznets (1956), Chenery (1960) and Denison (1967), the productivity gap in manufacturing sectors are analysed in cross-country static-comparative exercises. Price effects are also assessed and the results compared to Fagerberg (2000). Section 3.4 presents the empirical methodology and discusses the results of the exercises of productivity decomposition (shift-share) and counter-factual (McMillan and Rodrik, 2011). Section 3.5 estimates the impact of structural heterogeneity and structural change on growth econometrically. Different subsets of the sample are tested. The final section outlines the main findings and conclusions of the chapter.

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[81] The lack of criteria in the determination of the value added by service activities makes its measurement open to much criticism (Roncolato and Kucera, 2014).

[82] The period of analysis was determined by the availability of comparable cross-country data and compatibility of the period with the intra-sectoral database (see Chapter 4). For more detail on the database preparation and sample selection, please refer to Appendix 1.

3.2. Inter-sectoral re-allocation and growth: literature review

The measurement of the relative contribution of the process of structural change to growth has been one of the most prolific lines of research in the 'structural' and 'transformation literature' since the seminal works of Fabricant (1942) and Maddison (1952). Different methodologies centred either on demand and/or supply determinants were developed and adapted along the years. Historically, these studies confirm the importance of the reallocation of labour for growth, even though the variety of ways in which the relationship is measured creates contradictory results.

Amongst the most common decomposition techniques adopted in these studies, three stand out:

(i) The 'growth accounting' exercise: The technique decomposes growth in its proximate sources using accounting identities. In the neoclassical version, also called Abramovitz-Solow-Denison decomposition, it provides a framework for weighting the contribution of changes in factors inputs to growth. The residual, typically called 'total factor productivity' (TFP) responds for the improvement of technology. The disaggregation carried on in such exercises, however, not necessarily includes the component of structural change[83].

(ii) The 'structural decomposition': The method emphasizes demand elements. The point of departure is generally the static input-output model. Exogenous levels of consumption, investment and export for each of the specified products (together with the exogenous input requirements) are assumed as the main determinants of output and employment levels. In its simplest form, it disaggregates the output inter-temporal changes into changes in the demand for each of the industries and their input coefficients[84].

(iii) The 'shift-share' method: Commonly found in the Schumpeterian literature, the method proposed by Fabricant (1942) resembles the traditional 'analysis of variance' (ANOVA). It decomposes productivity growth in at least two components: the 'within' or intra-sectoral productivity growth, derived from the process of technological progress, and the 'between' or inter-sectoral productivity growth, originating in the process of inter-sectoral structural change. An element of interaction between these two is also commonly found.

For the purpose of this study, the shift-share presents the best fit. Amongst the advantages of the method, one should highlight: (i) it captures both demand and supply effects on productivity growth, with between effects representing the first and within effects the second; (ii) it enables a direct

[83] Bosworth and Collins (2008) and Fernald and Neiman (2011) present some recent application of the method.
[84] Syrquin (1988) and Dietzenbacher, Groot and Los (2007) are examples of the use of this method.

comparison of the relative importance of the process of structural change and technological deepening to growth; (iii) finally, it enables the inclusion of new determinants, creating several alternative interpretations for both the method and its results[85].

Empirically, the studies generally agree that the 'within effect' account for most of the productivity growth. Syrquin (1986) is an influential example. Applying the method for a large sample of developed and developing countries in the period from 1960 and 1983, he found that the reallocation effect amounted to an average of 30 percentage points of TFP change. The results vary with the country's income level, being higher in medium-income economies and almost null in high- and low-income economies. The author concludes that

> *"in the presence of significant differences in factor returns across sectors, structural change becomes an essential element in accounting for the rate and pattern of growth. On one hand, that change can retard growth if its pace is too slow or its direction inefficient. On the other hand, it can contribute to growth if it improves the allocation of resources"* (Syrquin, 1988, p.258).

The more recent contributions on the topic, however, have been defending a much smaller role for the structural change in the growth process. Apart from differences in the method, several factors concur in the explanation of the contrasting results between early and late works, but especially a change verified in the actual stage of the capitalism. Until the end of the 1980s, the traditional divide agriculture-industry-service was clear in the economic structure, being the first the backward and last two advanced sectors (especially manufacturing)[86]. Currently, however, much of the gap or 'structural heterogeneity' is found within manufacturing and service sectors. At one side, the process of technical change, price movements, and the drastic fall of employment in agriculture has increased the productivity of agriculture across the globe. On the other side, there has been a strong process of product differentiation especially in manufacturing in the past decades (Timer and Szirmai, 2000), even though the relationship between output, productivity and employment is more blurred within this sector (Fagerberg, 2000)[87].

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[85] Much of the method differentiation arises from the alternative interpretations of its residuals, derived from the application of year weights throughout the decomposition.

[86] Chapter 7 investigates patterns of specialisation and introduces some of the transformation stylised facts commonly found in the literature.

[87] Analysing the differences between his and Salter's (1960) results, Fagerberg (2000) argued that the technology change by the time of Salter's study was much more conducive to employment/output growth than in the period of his analysis. This corroborates the findings of previous studies with smaller country samples (e.g., Dollar and Wolff, 1988; Timmer and Szirmai, 1999).

Looking at the literature, however, few are the studies distinguishing the general process of structural change from the process of manufacturing structural change. Among the exceptions, the work of Salter (1960), and a more recent literature in the Schumpeterian tradition that focuses on East-Asian countries and their development process (Fagerberg, 2000; Timmer and Szirmai, 2000). Even in the latter, though, highly-aggregative sectoral breakdowns are adopted, leaving little space for the inter-sectoral structural change to manifest its influence, as section 3.4 will show.

Table 3.1 summarises this empirical literature. As shown, it privileges highly-aggregated sectoral breakdowns, which contributes to underscore the role of the structural change in the growth measured. The more recent study, Roncolato and Kucera (2014), for instance, consider only 7 sectors. Accordingly, they claim that the effect of labour reallocation on productivity was close to zero for most of the 81 countries in their sample covering the period between 1984-2008.

Table 3.1 - Shift-share empirical literature

Paper	Coverage	Period	Industry Breakdown (number of sectors)
Pieper (2000)	30 (developing)	1975-84; 1985-93	4
Ocampo *et al*. (2009)	57 (developed and transition)	1990-04	3
Timmer and de Vries (2009)	19 (Latin America and Asia)	1950-05	5
McMillan and Rodrik (2011)	38 (developed and transition)	1990-05	9
Roncolato and Kucera (2014)	81 countries	1984-98; 1999-08	7
McCombie (1980)	12 (developed)	1950-65; 1965-73	3
Timmer and Szirmai (2000)	4 asian countries	1963–1993	13
Fagerberg (2000)	39 countries	1973; 1990	24

Source: author's own elaboration

Adopting a 3 sectors sectoral breakdown, Ocampo *et al*. (2009) found that between effects were less relevant, but still important in some regions as the South-East Asia. The gap between these and Latin-American countries result from differences in the within-sector productivity trajectories though. Timmer and de Vries (2009) reached the same conclusion when evaluating a sample of nine Latin American and 10 Asian countries between 1950 and 2005. Based on unweighted averages for the 19 countries, the authors discovered that the within effects were far more important than labour reallocation effects.

Timmer and Szirmai (2000) examined the role of structural change in explaining aggregate productivity growth in the manufacturing sector of four Asian countries over the period 1963–1993. The conventional shift-share analysis was used to measure the impact of shifts in both labour and capital inputs. The results do not support the structural-bonus hypothesis. This finding is robust, even when the conventional shift-share analysis is modified to take into account increasing returns to scale, that is, to take into account the Verdoorn's law, as McCombie (1980) originally proposed. As in the latter, the returns to scale accounted for only a marginal effect. It is argued that improvements in productivity levels were widespread and depended negatively on the distance from the global technology frontier, confirming the 'Gerschenkronian notion of catch-up' (Ibid, p. 371).

McMillan and Rodrik (2011) is perhaps the only paper to argue for a more important role for the structural change element in the recent growth process. Based on a 9-sectors breakdown, the authors evaluated the process of growth of 38 developed and developing countries from 1990 to 2005. They found that the significant gap in productivity growth between Asia, on one hand, and Latin America and Africa, on the other, are due to the direction of the structural change effect and not the 'within effect', which vary much less between these groups of countries. This diverging conclusion results from both the study's emphasis on differences between these groups of countries and the adoption of a different weight for the between effect, which excludes the interaction effect. If not so, the results would be the same of the previous literature, as demonstrated by Roncolato and Kucera (2014).

3.3. Data and preliminary exploratory analysis

Both Kaldorian and Evolutionary traditions agree on the key importance of the manufacturing sector to growth. Nonetheless, the actual level of heterogeneity across and within manufacturing sectors and the role played by the distinct branches in the process are yet little explored (Fagerberg, 2000; Pagés, 2010). This section investigates the pervasiveness of the 'inter-sectoral heterogeneity' in manufacturing worldwide. The data is provided by the third version of the UNIDO Industrial Statistics Database (INDSTAT) and comprises annual information for 125 industrial sectors of 46 countries in the period 1991-2009. The database preparation and sample selection are presented in Appendix 1.

Assuming that there is labour/factor mobility across sectors, for the process of structural change to influence growth, it suffices either that: (i) productivity growth or levels differ across sectors; and/or (ii) prices movements do not equalise productivity returns across sectors. The following sub-sections introduce the productivity index and assess each of these hypotheses. The analysis adopts different aggregation levels to emphasise the influence of the sectoral breakdown in the resulting structural change effect on growth. Industrial sectors are assumed internally homogeneous. Regional and country group analysis help uncovering the role of other elements in the determination of patterns of specialisation and structural change[88].

3.3.1. The labour productivity index

The labour productivity index (l) is defined as the output (Q) per worker (L). In the numerator, the gross output series is used instead of the traditional measure of value added. This is due to the much superior completeness and balance across sectors and countries of the first database[89]. Also, since the number of hours worked was not available, the number of workers is used as the denominator.

Table 3.2 compares the basic statistics of the two measures of the labour productivity. In the first column the gross output is the numerator and in the second the value added. The correlation between these indicators is of 94%.

Table 3.2 - Labour productivity index: basic statistics

Statistics	Log (Q/L) (i)	Log (VA/L) (ii)
N	49062	46880
mean	15.899	14.872
sd	1.176	1.129
p25	15.212	14.175
p50	16.140	15.158
p75	16.643	15.577

Notes: (i) Prod=[output/employment]/price; (ii) Prod=[value added/employment]/price.
Source: author's own elaboration (data from UNIDO)

3.3.2. Sectoral analysis

For the labour reallocation to impact growth, the factor's productivity should differ across sectors. When labour moves from less to more productive activities, the economy should grow even if sectoral productivity rates remain unchanged. This is because the high-productivity sector increases in participation, but also because the productivity of the sector shedding labour might increase, supposing it has a non-unitary elasticity of employment substitution, i.e., diminishing returns to labour employment.

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[88] These are further explored in chapter 7.

[89] 24% of the information is missing at the 4-digit disaggregation for the latter. More importantly, the missing information is not distributed evenly across countries/regions, becoming a potential source of bias in the analysis. While only 2% of the total information is missing in South Asian countries, the non-response is higher than 30% for European countries.

Table 3.3[90] presents level and growth rates of the labour productivity index and its components for the 2-digit ISIC sectors in the sample. The global (sector-weighted) growth rate of productivity was of 1.2% per year in the period between 1991-2009. The overall unweighted average (displayed in the bottom of the table), is a little higher, of 1.42 percentage points, reflecting the fact that sectors with low participation in total labour employment display higher productivity growth rates.

Table 3.3 - Selected indexes by ISIC2 industrial activities: world economy, average (1991:2009)

SECTOR (2-digit ISIC CODE)	Average productivity* (prod)		Internal heterogeneity** (prod_sd)	Price index*** (P)		Output (Q)		Employment (L)	
	Level	Δ		Level	Δ	Total share	Δ	Total share	Δ
15	5.307	1.05%	123.06%	1.26	2.83%	0.12	1.34%	0.13	0.33%
16	5.781	-0.22%	173.60%	1.72	9.55%	0.01	-1.59%	0.01	-1.20%
17	4.895	-0.79%	88.44%	1.21	1.78%	0.03	-3.22%	0.06	-2.42%
18	4.815	-2.62%	96.27%	1.36	6.17%	0.01	-4.90%	0.05	-2.34%
19	4.891	-1.67%	89.80%	1.28	4.07%	0.01	-5.18%	0.02	-3.27%
20	4.958	0.17%	83.18%	1.37	4.44%	0.02	-1.30%	0.03	-1.41%
21	5.196	2.58%	69.85%	1.15	2.61%	0.03	0.79%	0.03	-1.72%
22	5.114	2.11%	144.35%	1.19	3.31%	0.04	1.51%	0.04	-0.55%
23	6.097	3.51%	133.02%	2.02	8.15%	0.05	0.94%	0.01	-2.26%
24	5.365	3.46%	110.74%	1.26	2.27%	0.09	2.83%	0.06	-0.62%
25	5.017	0.01%	73.48%	1.25	3.81%	0.04	1.22%	0.05	1.20%
26	5.025	0.38%	85.10%	1.31	3.55%	0.03	-0.59%	0.04	-0.93%
27	5.210	3.02%	82.37%	1.43	3.84%	0.05	0.76%	0.05	-2.18%
28	4.951	-1.41%	74.50%	1.35	4.94%	0.06	-0.89%	0.08	0.51%
29	5.045	1.03%	77.99%	1.24	3.18%	0.09	0.73%	0.09	-0.43%
30	5.423	5.17%	129.41%	2.04	3.26%	0.02	2.73%	0.01	-3.35%
31	5.049	3.01%	83.97%	1.33	1.31%	0.04	2.39%	0.05	-0.73%
32	5.250	7.49%	106.77%	1.36	2.10%	0.06	5.96%	0.04	-1.55%
33	4.973	1.56%	74.23%	1.52	5.77%	0.02	1.56%	0.03	0.00%
34	5.228	1.95%	112.11%	1.41	4.64%	0.11	2.00%	0.07	-0.08%
35	5.037	2.98%	82.37%	1.4	4.96%	0.03	2.36%	0.03	-0.57%
36	4.905	-1.55%	84.53%	1.3	4.33%	0.03	-2.20%	0.05	-0.72%
AVERAGE	5.161	1.42%	99.1%	1.39	4.1%	0.045	0. 3%	0.047	-1.1%
Standard Deviation	0.30	0.02	0.27	0.23	0.02	0.03	0.03	0.03	0.01

Notes: Δ represents the growth rate of the variable. * Measured as the logarithm of the output/employment ratio. ** Standard deviation of the sectoral productivity (across 4 digit sub-sectors) presented as a percentage of the average productivity. *** Worldwide price level (2000 as the base year).
Source: author's own elaboration (data from UNIDO)

[90] Table 3.2 aggregates output in constant prices and employment at the 2-digit ISIC classification for the World as a whole, that is, without country divisions. Although the choice is consistent with the question of what is the general dynamic of the sector worldwide, there are several flaws and limitations imposed by the availability and quality of data. Besides unaccounted cross-country price differences, one crucial problem is the lack of data for some countries in some years, which makes the sample unbalanced and, ultimately, different year by year.

The most dynamic sectors, *Radio, Television and Communication Equipment* (id.32) and *Office, Accounting and Computing Machinery* (id.30), account for little more than 4% and 1% of the total employment in the industrial sector (L), respectively. This confirms Fagerberg's (2000) findings that traditional industries – those geared towards private consumption – are increasing their participation in total employment, while the most dynamic are not. This aspect represents a change compared to Salter's (1960) findings, and is, according to the author, the reason why structural change – in a pure accounting sense – was "*more important for productivity growth previously than it appears to have been more recently*" (Ibid, 2000, p.409). This relationship is further discussed below.

The cross-sectoral differences in productivity are substantial. *Radio, Television and Communication Equipment* (id.32) grew at an average rate of 7.49% per year between 1990-2009. At the other extreme, *Wearing Apparel and Fur's* (id.18) productivity decreased by an average of 2.62%. *Coke, Refined Petroleum Products and Nuclear Fuel* (id.23) displays the highest level of productivity rate among the industrial sectors in the sample, followed by *Tobacco Products* (id.16), with only half of productivity of former though. The least productive sector, (id.18), for comparison, presents around 5% of (id.23)'s productivity. The inter-sectoral disparities ('external gap') are evidenced in the standard deviation of the productivity measure presented at the bottom of the table.

The actual gap, however, can be even larger, since statistical agencies often fail to distinguish between quality improvements, commonly assumed to be frequent in technologically progressive industries, and price increases (Griliches, 1979). Furthermore, considering the highly aggregated nature of the 2-digit classification, one should expect even larger differences in a more disaggregated sectoral breakdown.

This is confirmed in Table 3.4 where the highest and lowest productivity 4-digit ISIC sectors of the 22 2-digit industries are depicted. The variable Gap is the ratio of the minimum to maximum sub-sectors productivity for each of the 2-digit sectors. In the most homogeneous sector, *Rubber and Plastics Products* (id.25), the sub-sector of lowest average productivity *Other Rubber Products* (id.2519) reaches only 44% of *Rubber Tyres and Tubes* (id.2511), the sub-sector of highest average productivity. *Food and Beverages* (id.15) displays the highest internal gap, with *Bakery Products'* (id.1541) productivity reaching only 7.65% of *Prepared Animal Feeds* (id.1533) productivity. On average, the highest productivity subsector displays 3 to 4 times the productivity of the lowest productivity subsectors.

Table 3.4 - Maximum and minimum productivity by ISIC2 activity: average (1991-2009)

2-Digit ISIC	4-digit	Highest productivity subsector	PROD MAX	4-digit	Lowest productivity subsector	PROD MIN	Internal Gap*
15	1533	Prepared animal feeds	$556,000	1541	Bakery products	$42,545	7.65%
16	1600	Tobacco products	$365,000	1600	Tobacco products	$133,000	36.44%
17	1722	Carpets and rugs	$153,000	1723	Cordage, rope, twine and netting	$40,981	26.78%
18	1820	Dressing & dyeing of fur; processing of fur	$124,000	1810	Wearing apparel, except fur apparel	$42,784	34.50%
19	1911	Tanning and dressing of leather	$136,000	1912	Luggage, handbags, etc.; saddlery & harness	$30,707	22.58%
20	2021	Veneer sheets, plywood, particle board, etc.	$174,000	2029	Other wood products; articles of cork/straw	$51,435	29.56%
21	2101	Pulp, paper and paperboard	$303,000	2102	Corrugated paper and paperboard	$97,399	32.14%
22	2216	Publishing of recorded media	$256,000	2222	Service activities related to printing	$52,545	20.53%
23	2320	Refined petroleum products	$1,560,000	2320	Refined petroleum products	$102,000	6.54%
24	2413	Plastics in primary forms; synthetic rubber	$524,000	2424	Soap, cleaning & cosmetic preparations	$94,512	18.04%
25	2511	Rubber tyres and tubes	$164,000	2519	Other rubber products	$72,230	44.04%
26	2694	Cement, lime and plaster	$278,000	2692	Refractory ceramic products	$48,442	17.43%
27	2720	Basic precious and non-ferrous metals	$336,000	2731	Casting of iron and steel	$58,574	17.43%
28	2813	Steam generators	$165,000	2892	Treatment & coating of metals	$50,545	30.63%
29	2924	Machinery for mining & construction	$271,000	2926	Machinery for textile, apparel and leather	$57,441	21.20%
30	3000	Office, accounting and computing machinery	$309,000	3000	Office, accounting and computing machinery	$55,490	17.96%
31	3130	Insulated wire and cable	$296,000	3150	Lighting equipment and electric lamps	$39,894	13.48%
32	3220	TV/radio transmitters; line comm. apparatus	$377,000	3210	Electronic valves, tubes, etc.	$72,734	19.29%
33	3313	Industrial process control equipment	$188,000	3320	Optical instruments & photographic equipment	$36,578	19.46%
34	3410	Motor vehicles	$368,000	3420	Automobile bodies, trailers & semi-trailers	$62,199	16.90%
35	3520	Railway/tramway locomotives & rolling stock	$237,000	3520	Railway/tramway locomotives & rolling stock	$42,843	18.08%
36	3691	Jewellery and related articles	$145,000	3692	Musical instruments	$38,248	26.38%

Notes: * Ratio of Prod Min and Prod Max.

Source: author's own elaboration (data from UNIDO)

The internal gap can also be measured by the standard deviation of the cross-country productivity of sub-sectors. Table 3.2 presents these statistics as a percentage of the sector's average productivity. *Tobacco Products* (id.16) and *Printing and Publishing* (id.22) are the most heterogeneous sectors. *Paper Products* (id.21), *Rubber and Plastics Products* (id.25), *Medical, Precision and Optical Instruments* (id.33), and *Fabricated Metal* (id.28) are the ones for which the productivity measures are less dissimilar across the 3-dimensions: subsectors, time and countries.

Breaking down the productivity in its components, the gross output and employment, brings more information on the specific role of the sector in the process of development. Fagerberg (2000), for instance, noticed that

> "*[m]ore recently this relationship between output, productivity and employment has become more blurred. New technology, in this case the electronics revolution, has expanded productivity at a very rapid rate, particularly in the electrical machinery industry, but without a similarly large increase in the share of that industry in total employment. In fact, the industries that increased their role in total employment most substantially were generally traditional industries [...] with average to low productivity growth. Hence, in recent decades, new technology has not been linked with structural changes in demand, output and employment in the same way as before*" (ibid., p.409).

The level and growth rate of the two components of the productivity indicator are also depicted in Table 3.3. The gross output grew in 14 of the 22 sectors. The most dynamic sector, *Radio, Television and Communication Equipment* (id.32), experienced the output growing at an average rate of 6 percentage points per year, whereas the least dynamic sector, *Leather and Footwear* (id.19), reduced its output at an average rate of 3% per year during the two decades in study.

The comparison between the sectoral shares in output (Q) and labour employment (L) also reveals interesting patterns. *Coke, Refined Petroleum Products* and *Nuclear Fuel* (id.23) account for more than 5% of the total industrial output, but only to 0.5% of the total employment. The share in total output exceeds the share in total employment for only five industries. *Wearing Apparel and Fur* (id.18) and *Textiles* (id.17) can be highlighted amongst those for which the share in total employment exceeds the share in total output. The first presents an L-share 5 times its Q-share, whereas for the second the L-share is twice as big as the Q-share.

The total industrial employment decreased at an average rate of 1.1% per year, confirming Ocampo *et al*.'s (2009) claim that the *"industrial sector is the main motor for productivity increases but not for job creation*" (ibid., p. 47). The biggest labour shedders are *Office, Accounting and Computing*

Machinery (id.30) and *Leather products and Footwear* (id.19), for which the number of employees reduced at a rate superior to 3% per year. The few exceptions are *Rubber and Plastics Products* (id.25), *Food and Beverages* (id.15), and *Fabricated Metal Products* (id.28), which increased their employment in the period. The differences in output and labour growth rates evidence an important reallocation of labour in manufacturing sectors in the period. Apart from the fact that employment has plummeted in the industry as a whole, the mobility of the employment condition for structural change to influence growth.

Finally, Table 3.3 also reports the average sectoral price level and growth rate. "*In a globalized world, the differences in productivity growth rates between different sectors should be equalized by contrary movements in prices*" (Fagerberg, 2000, p.394). If, however, some sectors are able to keep most of the rewards from a faster technological progress to themselves, then the specialisation pattern become a very important element to the determination of the country growth rate. On average (unweighted), the world prices grew 4% per year in the period. Much of this reflects the rise of commodities prices in recent decades. *Tobacco Products* (id.16), *Coke, Refined Petroleum Products and Nuclear Fuel (id.23)* and *Wearing Apparel and Fur* (id.18) are the highlights. One can note that with some exceptions, as (id.23), it appears as if industries of high productivity growth had low price changes and vice-versa. This result confirms Fagerberg's (2000) conclusions and indicates that countries specialised in sectors with exceptional market power might enjoy of better economic results than their counterparts.

To investigate this hypothesis further, Table 3.5 presents estimates of the relationship between price growth and productivity growth for the 22 sectors in the 2-digit sample[91]. Following the neoclassical theory, in competitive markets, any reduction in costs should result in similar decreases in prices, which means a −1 coefficient for the relationship. In the extreme case that an industry has sufficient market power to keep the rewards from technological progress entirely to itself, there would be no relationship between price growth and productivity growth (in this case, the expected coefficient is zero).

[91] Since the calculation of productivity growth in constant prices depends on the same price indices that are used to calculate price growth, ordinary least squares would result in biased estimates. To avoid such bias, 2SLS and instrumental methods were adopted. In the latter, the productivity growth was instrumented by a set of country- and sector-specific variables correlated with it, but not with the price growth rate: initial productivity level, annual investment level, employment growth, size of the population and change in the sector's share of total manufacturing employment.

Table 3.5 - Productivity growth and price growth: cross country panel data estimation, average (1991-2009)

Industry (ISIC)	Productivity growth	Correlation	Std. error	h0: z=0 p > |z|	h0: z=1 p > |z|	R^2
15	-1.126	-0.280	0.012	**	***	0.078
16	-0.102	-0.028	0.090	-	***	0.001
17	-0.881	-0.420	0.170	***	-	0.176
18	-1.281	-0.464	0.467	***	-	0.215
19	-0.063	-0.279	0.484	-	*	0.078
20	-0.738	-0.529	0.234	***	-	0.280
21	-0.717	-0.328	0.264	***	-	0.108
22	-0.953	-0.513	0.231	***	-	0.263
23	0.995	-0.207	2.400	-	-	0.043
24	-0.563	-0.390	0.412	-	-	0.152
25	-0.478	-0.439	0.216	**	**	0.193
26	-1.155	-0.204	0.334	***	-	0.042
27	0.412	-0.125	0.334	-	-	0.016
28	-0.320	-0.241	0.196	*	***	0.058
29	-1.092	-0.498	0.190	***	-	0.248
30	0.011	-0.200	0.096	-	-	0.040
31	-0.477	-0.591	0.262	*	**	0.349
32	0.240	-0.475	0.668	-	-	0.226
33	-0.402	-0.561	0.119	***	***	0.315
34	-0.691	-0.432	0.302	**	-	0.187
35	-1.283	-0.460	0.551	***	-	0.212
36	-0.697	-0.636	0.156	***	*	0.405

Notes: 2SLS panel estimates.
- not significant* Significant at the 10% level. ** Significant at the 5%. *** Significant at the 1%.
Source: author's own elaboration (data from UNIDO)

The hypothesis that the coefficient is not different from zero is not rejected in less than one third of the cases. For these sectors, but especially for id.16 – where price changes and productivity changes have a low correlation – and id.23, id.27, and id.32 – where the coefficients were positive, though not significantly different from zero – one should acknowledge a high market power for the firms. With the exception of id.32, these are 'low-tech' and/or commodity sectors, for which prices have increased in the last decade.

For another one third of the sectors, the estimated coefficient is high in absolute value and not significantly different from −1. In special, this is the case for id.18 and id.35. These are fairly competitive industries, for which very low or no market power can be observed in the aggregate data.

Lastly, there is a group in the intermediate range, indicating some, though incomplete, spillovers from technological progress to prices. This group includes some relatively unsophisticated manufactures, mostly destined to consumption id.15, id.25, and id.28, but also *Medical, precision and optical instruments* (id.33), and *Electrical machinery and apparatus* (id.31), some of the most advanced (high-tech) industries.

Differently from Fagerberg (2000), the results show that firms in high-tech industries have an important level of market power, though yet below firms in commodity sectors. On the other side, traditional industries are the most competitive. Once again, the results appear to confirm the hypothesis that price trajectories do not equalise the productivity differential across sectors, but, on the contrary, contribute to generating more heterogeneities, what explains why developing countries specialised in traditional sectors performed poorly compared to the ones specialised in commodities and/or more advanced sectors.

3.3.3. Regional and country analysis

Table A1 in Appendix 1 presents the basic statistics above by country. On average, industrial productivity has grown 2.82% per year, little above the 2.3% found by Fagerberg (2000) for the period between 1973 and 1990. There are large gaps within and between the countries in the sample. The results show that countries from the Central and South-East Europe experienced a much higher rate of productivity and gross-output growth in the more recent period. On the opposite side, Latin-American countries performed worse in the period[92].

Table 3.6 presents the statistics grouped by regions. The results indicate that high-income countries performed better[93], especially compared to Latin-American countries. By sub-periods, the global performance of the productivity indicator was significantly higher in the 2000s compared to the 1990s.

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[92] Country comparisons are complicated by the fact that the sample period vary between them. In addition, the average number of sectors considered differs between the countries in the sample. The lower the number of sectors, the higher the potential misrepresentation of the country real industrial production structure. This might be a problem especially for the case of Brazil, Argentina, Israel, Qatar and Panama, countries for which the sectoral composition is underrepresented in the database.

[93] Different regional aggregations tell the same story: African and Latin-American countries perform worse than European and OECD countries. The most dynamic are East-Asian countries.

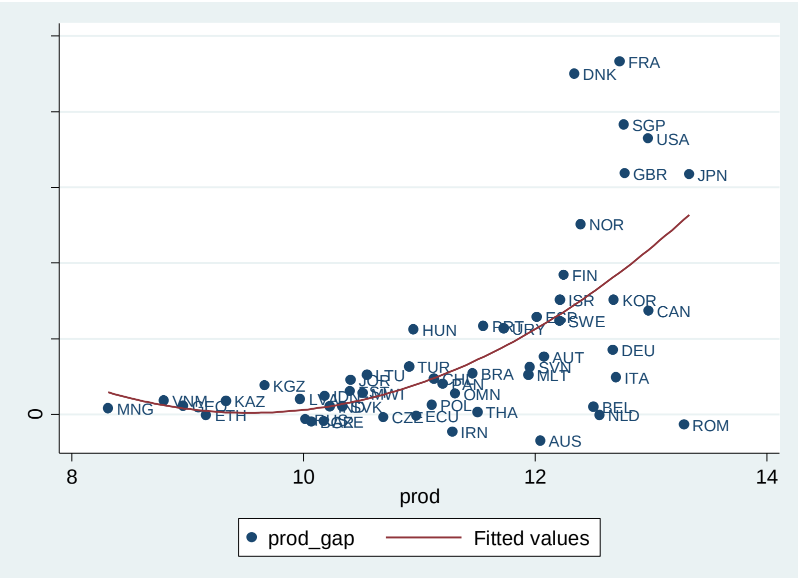
Table 3.6 – Growth rates of labour productivity components by periods and regions

Region	Period	Prod growth (Δprod)	Price growth (p)	Output growth (q)	Employment growth (l)
East Asia & Pacific	1991-1999	3.89%	-3.82%	1.64%	-2.19%
	2000-2009	2.06%	3.79%	2.90%	0.88%
	Total	**2.52%**	**2.69%**	**2.65%**	**0.18%**
Europe & Central Asia	1991-1999	1.91%	-0.33%	2.33%	0.61%
	2000-2009	4.20%	8.45%	3.11%	-1.09%
	Total	**3.75%**	**6.34%**	**3.01%**	**-0.70%**
Latin America & Caribbean	1991-1999	1.89%	-2.13%	3.20%	1.40%
	2000-2009	0.64%	1.77%	1.33%	0.84%
	Total	**0.78%**	**0.38%**	**2.42%**	**1.82%**
Middle East & North Africa	1991-1999	-1.62%	-1.03%	0.70%	3.27%
	2000-2009	2.75%	13.50%	5.23%	3.49%
	Total	**1.78%**	**11.75%**	**4.55%**	**3.95%**
North America	1991-1999	3.99%	-1.23%	3.86%	-0.09%
	2000-2009	2.65%	3.17%	0.34%	-2.17%
	Total	**3.10%**	**1.53%**	**1.60%**	**-1.38%**
South Asia	2000-2009	5.35%	7.24%	9.08%	3.65%

Source: author's own elaboration (data from UNIDO)

The gap is particularly relevant for countries with *Coke, Refined Petroleum Products and Nuclear Fuel* enclaves. Due to the fact that these are capital intensive sectors, the labour productivity tends to be extremely high. As McMillan and Rodrik (2011) argue, it is more meaningful to compare productivity levels across sectors with similar potential to absorb labour. The data, however, show that the disparities are still quite large. In special, the poorer the country, the higher the productivity gap for similar sectors.

Figure 3.1 - Productivity gap between high-tech and low-tech sectors by income per capita: average (1991-2009)



Notes: Horizontal axis = log(income); Vertical axis = gap = average prod of high-tech minus the average productivity of low-tech sectors in the country.
Source: author's own elaboration (data from UNIDO)

Comparing the productivity gap reported in Table A1 and Table 3.3, it becomes clear that the differences in productivity growth are bigger across countries than industries. This informs us that the failure of productivity statistics to account for qualitative changes is less of a problem at the aggregate level than at the level of the individual industry. For instance, unmeasured quality advances in a supplier industry often end up as measured increases in output in user industries, and would hence affect the aggregate productivity growth (McMillan and Rodrik, 2011).

Figure 3.1 illustrates another interesting stylised fact revealed by the data: the productivity gap between high-tech and low-tech sectors according to Lall's (2000) classification. This increases non-monotonically with the level of productivity. The reasoning is rather simple: poor countries have fewer high-tech sectors and these are, in general, not as productive as their counterparts in the developed world. The closer is a country from the technological frontier, the larger will be the productivity gap between their more and less advanced sectors, even though the internal gap is lower in these countries (when considered all sectors of the economy).

3.4. Productivity decomposition

The last section provided clear evidence of the existence of large structural heterogeneities in manufacturing. The satisfaction of the stated conditions endorses the idea of a significant role for the process of structural change in the growth process. Accordingly, this section moves on to measuring how much of the productivity growth is explained by structural change. The rest of this chapter will focus on assessing the quantitative importance of labour reallocation to growth. Three different methods at different levels of aggregation of the data are discussed.

3.4.1. Shift-share

The shift-share approach derives from the supply-side neoclassical growth-accounting method. Pioneered by Fabricant (1942) and Maddison (1952), it has received many recent applications in the Schumpeterian literature (Jorgenson, 2001, 2005; Fagerberg, 2000; Timmer and Szirmai, 2000). Following the version adopted by these authors, define labour productivity ($prod$) as follows:

$$prod = \frac{Q}{L} = \frac{\sum Q_i}{\sum L_i} = \sum\left(\frac{Q_i}{L_i} \times \frac{L}{\sum L_i}\right) \qquad (3.1)$$

where Q is the value added (or output) and L the labour input. The subscript i indexes the industry. Defining the labour productivity in sector i as $prod_i = \frac{Q_i}{L_i}$ and the share of sector i in total employment as $S_i = \frac{L_i}{\sum L_i}$, then (3.1) can be rewritten as $prod = \sum prod_i S_i$. Knowing that Δ represents the difference between the actual and previous period, and using growth rates it becomes:

$$\Delta prod = \sum \left(\frac{prod_{it-1} \Delta S_i}{prod_{t-1}} + \frac{\Delta prod_i \Delta S_i}{prod_{t-1}} + \frac{S_{it-1} \Delta prod_i}{prod_{t-1}} \right) \tag{3.2}$$

The first term on the right side $\left(\sum \frac{prod_{it-1} \Delta S_i}{prod_{t-1}} \right)$ represents the contribution to productivity growth from changes in the allocation of labour between industries, that is, the structural change effect (SC). It is positive when the country shifts labour to higher productivity activities. The second term $\left(\sum \frac{\Delta prod_i \Delta S_i}{prod_{t-1}} \right)$ represents the interaction between changes in productivity in individual industries and changes in the allocation of labour across sectors (FR). It is positive when the country shifts labour towards industries with higher productivity growth rates. Finally, the last term $\left(\sum \frac{S_{it-1} \Delta prod_i}{prod_{t-1}} \right)$ measures the contribution of the growth of the internal productivity of each sector, also known as productivity within (PW).

McMillan and Rodrik (2011) adopt a slightly different decomposition, which assumes the existence of only two elements: the within productivity growth (PW), determined by capital accumulation, technical change, or reduction of misallocation across plants; and the between productivity growth (PB), due to the shift of labour from low to high-productivity sectors.

$$\Delta prod = \sum \Delta prod_i S_i + \sum prod_i \Delta S_i \tag{3.3}$$

In practical terms, the difference between (3.3) and (3.2) is that the multiplicative term (FR) adds to the structural change component (SC), that is PB=SC+FR. In fact, if there is no structural heterogeneity across sectors, neither SC nor FR would exist, then adopting a simpler disaggregation, without the interaction term, render more justice to the structural change element in the decomposition.

The shift-share method has received a vast criticism, from its static nature to the fact that no causality can be claimed in the relationship. A number of other limitations might also result in an under/over-estimation of the structural change element, as pointed out by Timmer and Szirmai (2000): (i) the sectoral breakdown considerably influences the results, as aggregative analyses omit the structural change in sub-sectors; (ii) the assumption that the marginal productivity equals to the average productivity, which makes the productivity in a sector independent of factors moving in or out the industry; (iii) the assumption of input homogeneity, which might overvalue the impact of structural change if resources shift from low-skill to high-skill sectors; (iv) the incidence of spillovers, as the product of some sectors might impact others' output; and (v) the causal links between output growth and productivity increase (increasing returns to scale), which would underestimate the impact of structural change effect.

Table 3.7 presents the annual average value of the productivity index decomposed by the elements above using the 4-digit ISIC classification. Both the actual contribution and its share on the country growth rate are presented[94]. Differently from the literature on the topic, which usually chooses 2 points in the series, annual averages are presented . It is believed that these smooth period-specific changes, delivering a more consistent picture of the importance of each element.

Table 3.7 - Productivity decomposition by shift-share: average (1991-2009)

COUNTRY	ANNUAL AVERAGE PRODUCTIVITY GROWTH (Δprod)	PROD BETWEEN (PB)			PROD WITHIN	
		SC	FR	Share*	PW	Share*
Jordan	-1.74%	-0.37	-1.38	99.70%	0.01	0.30%
Estonia	2.37%	3.20	-0.51	91.97%	-0.32	8.03%
Turkey	-1.03%	-4.52	5.27	84.70%	-1.77	15.30%
Russian Federation	2.73%	18.88	-23.91	84.64%	7.76	15.36%
Ecuador	-0.61%	1.67	-1.27	74.54%	-1.01	25.46%
Indonesia	1.15%	1.83	-2.63	69.64%	1.94	30.36%
Uruguay	-1.71%	-2.35	-1.42	64.71%	2.05	35.29%
Australia	2.16%	1.51	-1.38	58.83%	2.03	41.17%
Malaysia	1.75%	1.21	-1.52	56.94%	2.06	43.06%
Panama	2.49%	1.90	-9.68	52.99%	10.27	47.01%
Norway	1.13%	0.62	-0.77	52.06%	1.28	47.94%
Denmark	6.07%	3.19	-1.16	51.88%	4.03	48.12%
Bolivia	3.12%	1.60	-1.24	50.76%	2.76	49.24%
Argentina	-1.39%	0.87	-0.71	50.62%	-1.54	49.38%
Italy	-1.17%	-0.13	-0.45	49.50%	-0.59	50.50%
Latvia	6.82%	3.25	-2.13	48.57%	5.70	51.43%
Bulgaria	1.80%	-6.48	-1.20	44.77%	9.48	55.23%

[94] Because some elements present negative values, the shares were calculated as quotients of the absolute value of the component in relation to the sum of the absolute value of all components (i.e., pw+es+pf).

Cont. Table 3.7

Singapore	0.53%	-1.21	-0.43	43.02%	2.17	56.98%
Peru	0.87%	-1.34	-1.32	42.99%	3.52	57.01%
Canada	2.30%	0.61	-2.21	42.01%	3.90	57.99%
Germany	1.11%	0.03	0.42	40.99%	0.66	59.01%
Qatar	1.92%	-2.06	-0.49	36.32%	4.47	63.68%
Brazil	-3.04%	-1.01	-0.02	33.99%	-2.00	66.01%
Spain	0.74%	0.20	-0.12	32.18%	0.66	67.82%
Slovenia	3.33%	0.83	-0.58	31.38%	3.08	68.62%
Hungary	6.22%	1.58	-0.29	27.42%	4.94	72.58%
Colombia	2.58%	-1.04	-0.47	27.02%	4.09	72.98%
Ukraine	9.94%	1.87	-1.66	26.60%	9.73	73.40%
France	3.01%	0.27	-0.86	24.02%	3.60	75.98%
United Kingdom	3.56%	0.41	-0.84	23.72%	3.99	76.28%
Portugal	3.23%	-0.42	-0.80	21.44%	4.45	78.56%
Netherlands	1.26%	-0.02	-0.40	20.01%	1.68	79.99%
Morocco	2.53%	-0.29	-0.47	18.72%	3.29	81.28%
Sweden	4.12%	0.38	-0.60	18.46%	4.34	81.54%
India	5.50%	0.42	-0.69	16.08%	5.78	83.92%
Austria	3.50%	-0.48	-0.35	16.01%	4.33	83.99%
Israel	4.33%	0.42	-0.24	13.68%	4.16	86.32%
United States of America	3.97%	0.43	-0.13	13.27%	3.68	86.73%
Belgium	1.67%	0.08	-0.16	12.11%	1.75	87.89%
Japan	3.82%	0.29	0.04	8.46%	3.49	91.54%
Mexico	4.95%	0.27	-0.09	7.15%	4.77	92.85%
Finland	5.87%	0.24	-0.17	6.58%	5.81	93.42%
Czech Republic	6.47%	0.15	-0.13	4.26%	6.45	95.74%
Republic of Korea	6.08%	0.08	-0.11	2.92%	6.10	97.08%
AVERAGE	**2.70%**	**0.56**	**-1.33**	**38.08%**	**3.46**	**61.92%**

Note: * Share of the element in the sum of absolute values of PB and PW.
Source: author's own elaboration (data from UNIDO)

The results are striking. On average, the structural change element accounts for 40% of the cross-country productivity change, leaving the technical change with the 60% remaining, even though there is a high variance in the sample. For instance, in Jordan, almost all the negative productivity growth in the period is due to the structural change effect (PB), while in Korea, this component accounts for less than 3% of the productivity increase.

The negative effect of the FR component should be emphasised. On average, the interactive term reduced the potential of growth worldwide in 1.33 percentage points. This indicates that most of the labour shifts in the period were directed to industries with lower productivity growth rates, as this element measures the interaction between changes in productivity in individual industries and changes in the allocation of labour across sectors (Fagerberg, 2000). On the other side, the average absolute contribution of the SC component to growth was of 0.56 percentage points. Positive values for this element indicate that labour moved from low to high productivity sectors.

These results diverge considerably from most of the recent empirical literature on the topic, for which the structural change element has only a marginal effect on the productivity growth. Roncolato and Kucera (2014), for instance, found that out of the 2% average productivity growth in the period from 1984 to 2008, the reallocation element contributed with only 0.2%, less than 10% of the total. Their results are in line with the findings in Ocampo *et al*. (2009) and Timmer and de Vries (2009), Fagerberg (2000) and other studies based on much smaller country samples (Dollar and Wolff, 1988; Timmer and Szirmai, 1999).

The rather odd results of this chapter have a simple explanation though: it is based on a much more disaggregated database. While most of the previous studies adopt the traditional agriculture-industry-services data breakdown, this study analyses labour movements across 93 sectors per country, on average. It is obvious that the more sectors are included, the higher the impact of the structural change element on growth. Nevertheless, instead of highlighting the importance of the level of data disaggregation for the results, the literature usually obliterates the influence of the labour reallocation to growth matters.

The method adopted here, closer to McMillan and Rodrik (2011), also contribute for the results, although this study focuses on manufacturing sectors only. Few studies looked exclusively to this sector: Fagerberg (2000), Timmer and Szirmai (2000), and Salter (1960). Comparisons with these studies, however, are hampered by both the sectoral breakdown, and the period under analysis.

Table 3.8 illustrates the effect of sectoral breakdown in the measurement of impact of the structural change (PB) on growth. The countries are separated by income groups to show a different perspective. As seen, the relative participation of PB on growth reduces considerably with the level of data aggregation for all country groups.

Table 3.8 - Shift-share by income-groups: average (1991-2009)

INCOME GROUP	4 Digit (125 sectors)	3 Digit (61 sectors)	2 Digit (22 sectors)	1 Digit (3 sectors)
High income: OECD	31.32%	29.14%	24.16%	9.06%
High income: nonOECD	41.06%	40.54%	33.38%	10.95%
Lower middle income	24.98%	23.70%	26.32%	9.96%
Upper middle income	32.03%	29.41%	25.13%	16.48%

Source: author's own elaboration (data from UNIDO)

Table 3.9 presents the weighted averages of the disaggregation by region and decades. The total influence of the structural change is negative for all regions. The better results found in high-income regions result from both a higher PW and a closer to zero PB. The most important conclusion drawn from this table, however, is that the importance of the structural change component is increasing in time. This result corroborates the hypothesis in the Schumpeterian literature that the recent process of product differentiation contributes to increase the heterogeneity in manufacturing, making the structural change process even more relevant in the current period compared to previous decades.

Table 3.9 - Shift-share by periods and regions

REGION	SUB-SAMPLE	PROD GROWTH (Δprod)	PW		PB	
			value	share	value	share
East Asia & Pacific	1991-1999	3.80%	0.040	80.79%	-0.002	19.21%
	2000-2009	2.21%	0.027	74.45%	-0.004	25.55%
Europe & Central Asia	1991-1999	1.43%	0.019	65.30%	-0.005	34.70%
	2000-2009	3.91%	0.045	68.28%	-0.006	31.72%
Latin America & Caribbean	1991-1999	1.84%	0.039	67.60%	-0.021	32.40%
	2000-2009	0.69%	0.010	62.92%	-0.003	37.08%
Middle East & North Africa	1991-1999	-1.56%	-0.007	64.72%	-0.008	35.28%
	2000-2009	2.74%	0.039	57.08%	-0.011	42.92%
North America	1991-1999	3.99%	0.044	83.71%	-0.004	16.29%
	2000-2009	2.71%	0.037	70.03%	-0.010	29.97%
South Asia	1991-1999	-	-	-	-	-
	2000-2009	5.50%	0.058	86.80%	-0.003	13.20%

Source: author's own elaboration (data from UNIDO)

3.4.2. Counter-factual analysis

An alternative to the measurement of the importance of structural change for productivity growth is McMillan and Rodrik's (2011) counter-factual exercise. Differently from growth accounting approaches, where total productivity is disaggregated into some pre-defined components, the method consists of promoting a 'virtual' reallocation of labour towards a benchmark pattern (the sectoral allocation in the country of highest productivity) while holding constant the actual levels of sectoral productivity and vice-versa. The total aggregate productivity of labour ($prod$) in any country y is then measured before (t0) and after (t1) the structural change takes place. Formally:

$$prod_b = prod_{y,t1} - prod_{y,t0} \tag{3.4}$$

$$prod_w = prod_x - prod_{y,t1} \tag{3.5}$$

Where $prod_b$ is the 'productivity between' and $prod_w$ the 'productivity within'. $prod_x$ is the productivity growth rate in the benchmark country x. Both $prod_b$ and $prod_w$ can be positive, negative or null. The sum ($prod_b + prod_w$) gives country y's actual productivity growth rate. Equation (3.4) gives the potential productivity 'gain' due to the sectoral reallocation of factors, and (3.5) the potential productivity 'gain' due to the adoption of the best production methods and increases in factors quantity.

A number of conditions are necessary for these measures to make sense. Among them, one shall highlight at least two: (i) the sectoral technological trajectories are expected to equalise in different countries; and (ii) the ideal composition of sectors (benchmark) is also common to all countries. There are many other limitations of the method, as the discretionary choice of the benchmark structure, but these two are more serious, as they go against some important stylised facts of the transformation literature. Nevertheless, the method outperforms and complements shift-share analysis in at least one respect: the important indirect effects generated by externalities and increasing returns to scale do not underestimate the measure. Therefore, the method presents a ceiling to the shift-share, revealing the potential gain in shifting the actual allocation towards an 'optimal' pattern of specialisation.

The results of the application of the counterfactual exercise to the database are depicted in Table 3.10. On the left side of the table, the average specialisation pattern of OECD countries is adopted as the benchmark. On the right side the United States works as benchmark country. The results are fairly comparable in both cases. ΔPB represents the potential gain in productivity that the country would experience if the distribution of labour in the country were to be the same as found in the benchmark (considering the actual level of productivity in the country). ΔPW is the gain in productivity if the internal productivity of the sectors of the country were to equal the benchmark's. The importance of the structural change varies considerably across countries.

Table 3.10 - Counter-factual analysis: average (1991-2009)

COUNTRY	Δ PB*	Δ PW**	COUNTRY	Δ PB*	Δ PW**
Peru	157.90%	497.86%	Peru	132.38%	815.02%
Portugal	70.19%	102.66%	Portugal	55.01%	216.09%
Indonesia	69.68%	1305.30%	Indonesia	47.39%	2188.83%
Morocco	34.96%	360.07%	Morocco	17.52%	601.45%
Japan	26.45%	-45.66%	Japan	11.25%	-3.53%
Slovenia	23.61%	144.86%	Slovenia	11.06%	264.88%
Italy	23.50%	0.16%	Italy	9.17%	56.39%
India	18.54%	791.83%	Spain	8.47%	107.39%
Spain	16.17%	29.09%	United Kingdom	7.27%	61.01%
United Kingdom	13.55%	0.96%	Germany	4.39%	84.71%
Germany	12.79%	14.76%	India	4.09%	1228.56%
Turkey	10.63%	163.05%	Canada	2.71%	41.17%
United States of America	10.52%	-37.36%	France	1.30%	53.19%
Canada	8.29%	-10.74%	**AVERAGE (gain)**	**24.00%**	**439.63%**
France	8.25%	-5.51%	United States of America	0.00%	0.00%
Austria	6.96%	9.54%	Turkey	-3.89%	305.17%
Republic of Korea	5.93%	-8.96%	Hungary	-4.44%	447.54%
Hungary	5.71%	231.46%	Austria	-5.65%	79.77%
Latvia	0.89%	658.96%	Republic of Korea	-6.24%	64.62%
AVERAGE (gain)	**27.61%**	**221.18%**	Denmark	-7.91%	77.75%
Colombia	-0.82%	212.99%	Norway	-7.94%	40.93%
Denmark	-1.60%	14.07%	Colombia	-9.40%	372.97%
Norway	-1.75%	-2.02%	Latvia	-10.10%	1020.55%
Bulgaria	-2.59%	907.12%	Malaysia	-11.93%	446.05%
Malaysia	-4.10%	166.53%	Ukraine	-12.36%	2647.27%
Ukraine	-4.43%	1831.49%	Belgium	-13.34%	31.86%
Belgium	-4.85%	-14.15%	Estonia	-14.02%	668.59%
Estonia	-6.83%	405.04%	Bulgaria	-15.69%	1472.08%
Mexico	-10.57%	106.19%	Sweden	-19.75%	73.74%
Sweden	-10.90%	2.12%	Mexico	-21.35%	222.94%
Australia	-17.37%	68.03%	Netherlands	-21.41%	25.35%
Netherlands	-19.95%	-25.72%	Finland	-27.49%	53.60%
Finland	-20.19%	-4.82%	Australia	-29.21%	151.63%
Jordan	-23.59%	551.74%	Czech Republic	-32.17%	565.92%
Czech Republic	-24.71%	293.24%	Jordan	-32.74%	824.98%
Ecuador	-29.25%	241.97%	Singapore	-38.28%	86.23%
Singapore	-35.78%	-8.98%	Ecuador	-38.47%	382.61%
Uruguay	-38.25%	179.28%	Uruguay	-39.47%	303.38%
Brazil	-39.66%	239.66%	Brazil	-42.40%	434.14%
Russian Federation	-48.34%	1436.66%	Panama	-52.98%	380.25%
Panama	-49.62%	233.82%	Bolivia (Plurinational State of)	-57.32%	662.43%
Bolivia (Plurinational State of)	-53.98%	422.58%	Ireland	-59.31%	-13.72%
Ireland	-54.06%	-51.73%	Russian Federation	-64.05%	2051.75%

Cont. Table 3.10

Argentina	-66.57%	122.29%	Argentina	-70.83%	230.27%
Qatar	-66.66%	296.21%	Qatar	-71.06%	388.34%
Israel	-67.44%	37.22%	Israel	-74.17%	181.44%
AVERAGE (loss)	**-27.07%**	**294.65%**	**AVERAGE (loss)**	**-29.53%**	**473.56%**

Notes: Results ordered by PB. Notes: * PB is the hypothetical productivity should the country displayed the same labour allocation of the benchmark country. ** PW is the hypothetical productivity should the country presented the same levels of productivity for each size class as the benchmark country.
Source: author's own elaboration (data from UNIDO)

The Spearman's rank correlation coefficient between PB and PW is -0.06, indicating a small but negative relationship between the two. The probability of rejection of the null hypothesis that both are independent is of 0.69.

3.5. Econometric analysis

The conclusions in the previous sections are based on descriptive exercises and thus cannot be generalised over periods and/or units. This would require knowing the distributive characteristics of the variables and the estimation of a probabilistic relationship. This section presents a dynamic econometric model and discusses its results. If growth results from either structural change and/or TFP increases, one may define it as in Equation (3.3):

$$\Delta prod_{i,t} = \propto_0 + \propto_1 log(SC)_{i,t} + \propto_2 \Delta TFP_{i,t} + \beta X_{i,t} + \mu_{i,t} \qquad (3.6)$$

That is, productivity growth ($\Delta prod$) at a country i is explained by changes in the composition of the sectors (SC - between effect) and changes in the internal productivity (ΔTFP - within effect). $\propto_0$ is a constant term adopted in some estimations and $\mu_{i,t}$ is a error term. A set of control variables (X) is included to minimise the potential channelization of the effect of omitted variables in the coefficients of the explanatory.

The structural change is defined as the country's standard deviation of changes in the sectoral shares in total employment. The within effect is measured by the log-difference in TFP[95]. Macroeconomic, institutional, structural and external economy variables are included as controls. This comprises: (i) total population; (ii) human capital index; (iii) share of exports in the GDP; (iv) real exchange rate; (v) internal gap; and (vi) initial product. The interaction between SC and ΔTFP was also included in

[95] The TFP and all the control variables were drawn from the Penn World Table 9.0. Available at < https://www.rug.nl/ggdc/productivity/pwt/>.

some specifications. Lags of the explanatory, and regional and year dummies were also tested or used as instruments.

Panel data present a number of advantages over time-series and cross-sections. Nevertheless, the approach can suffer from the problems of both, what requires different strategies for the correct inference. Pooling data on very heterogeneous individuals is of special concern in cross-country growth analysis. This has been discussed by a number of authors (Arestis, Luintel and Luintel, 2010). See APPENDIX 3 for a discussion on panel data methods.

Table 3.11 - Structural change and growth: cross-country, panel data estimation (1991-2009)

Variable	Fixed-effects (FE)			FE - IV	Diff-GMM (orthog)	System-GMM		
ΔProd	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
SC	-0.051*	-0.076*	-0.083*	-0.086***	-0.073*	-0.074***	-0.076**	-0.06
ΔTFP	0.234*	0.512**	0.500**	0.519***	0.534**	0.812**	0.771**	0.484
Gap	0.083	-0.004			-0.010	0.111**	0.123**	0.2**
FR		-0.0008	-0.0012		-0.001	0.0011	0.0012	-0.001
$\Delta Prod_{t-1}$							-0.1233	
Log(Human capital)						0.0351	0.0482	0.067
Log(Population)			-0.0011***					
Log(Exports)			0.0001					
Log(Exchange rate)			-0.014					
Log(Investment)			0.0268					
$Log(Investment)_{t-1}$			-0.014					
Dummies 1990s			0.0087					
Dummies Asia			0.0621					
Dummies Africa			0.0195					
Dummies Al			0.0287					
Constant	-0.2786	-0.4883*	-0.6419	-0.5395**		-0.5069*	-0.5480*	-0.48
Observations	306	144	142	144	108	144	144	47
R^2	0.15	0.37	0.4	0.37				
Corr (u, b)	-0.5614	-0.6337	-0.9861	-0.6374				
F	2.4454	46.5536	17.2091		10.6896	6.2066	12.7259	25.56
Sargan (p-value)					0.3486	0.6402	0.3417	0.545
Hansen					30.4915	30.989	29.3256	15.47
Chi^2				63.746				

Notes: Standard deviation in parenthesis. * Significant at 5%. ** Significant at 0.5%. *** Significant at 0.1%.
All p-values corrected by White's robust variance. Model (v) uses gap and FR as instruments for SC.
Source: author's own elaboration (data from UNIDO)

The results of the estimation of Equation (3.6) considering the existence of non-measurable fixed-effects and different specifications are presented in Table 3.11[96]. The standard errors were corrected by White's robust variance method. As expected, the structural change element has a significant and negative impact on productivity growth[97]. A 1% increase in the standard deviation of the sectoral composition would cause a reduction between 0.05-0.09% of the productivity index. By comparison, 1% increase in the growth rate of TFP would increase the productivity growth rate by circa 0.5-0.8%. The results are statistically significant and consistent in different specifications.

Some specifications included a proxy for FR, the dynamic joint effect of PB and PW present in Equation (3.2). FR was proxied by the product of the annual change in the sectoral shares of employment and the annual change in TFP. The inclusion of FR as PB*PW would cause the automatic exclusion of one of the coefficients by multicolinearity. Although not significant in none of the specifications, the presence of FR increases considerably the R^2 and halves the heteroskedasticity of residuals.

As for the controls included, all presented very small or non-significant effect in most of the specifications. Equally, the year and regional dummies[98] did not result in a significant coefficient nor it reduced the heteroskedasticity in the estimation, which continued high, as the analysis of the residuals show. This is illustrated in specification (iv), where the only significant control, the log of population, presents a coefficient very close to 0. The effect of the human capital index (based on schooling years), exports, exchange-rate and investment (both actual and previous) all are in the expected direction, even though none are significant. The estimates of SC, Gap (measured as the difference between the productivity of the highest- and lowest-productivity sector) and ΔTFP are not changed by the inclusion of these variables in the model and the gain in R^2 is minimal[99].

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[96] The results for the Hausman, Breusch and Pagan test indicate that one cannot reject the hypothesis that individual specific effects are potentially correlated with regressors, justifying the choice for the model with fixed-effects.

[97] According to the shift-share exercise, because SC=FR+PB and the effect of FR is bigger than that of PB, the estimate of SC was expected to be negative. A negative FR indicates that most of the labour shifts in the period were directed to industries with lower productivity growth rates, while a positive PB would show that labour tends to move from low to high-productivity sectors.

[98] In order to capture heterogeneous effects beyond the specific individual effects measured by the fixed-effects component, i.e., the institutional differences between countries, the same specifications were estimated for regional subsets of the data. This resulted in a poor strategy, as the number of observations was significantly reduced, impacting the degrees of freedom and thus the significance of the coefficients.

[99] Also, the correlation between residuals and independent variables are greatly increased with their inclusion.

In order to reduce the disturbance in the model, Column (iv) gives the result for the more parsimonious specification, now using both Gap and FR, since these capture the different dimensions of the element, as instruments for SC. The FE-IV model returned a highly significant specification (p-value for Chi^2=0).

Since the structural change process would have no impact on growth if there would be no structural heterogeneity, gap is a key variable in correct specification of Equation (3.6). Nevertheless, its direct inclusion in the FE models, specifications (i) to (ii), returned a non-significant coefficient. A different strategy was to include a multiplicative term between gap and SC, but this reduced the latter's estimate and returned a positive coefficient for the former, as expected. In the absence of SC, the term proxies for it, returning a significant and negative coefficient very close to SC estimates. This indicates that the productivity gap is a key element in the growth process and is indeed significant for the impact of SC.

Finally, because the model includes potential endogenous elements, it is also important to consider strategies to deal with the endogeneity problem in the specifications. Since fixed-effects are considered poor instruments in the presence of endogeneity, a more accurate estimate of the relationship is only obtained by using the 'Generalized Method of Moments' (GMM). Two different dynamic models were tested: the GMM-system and GMM-diff (Cameron and Trivedi, 2005). Columns (v) to (viii) display the results for these models. In all cases, lags of SC and ΔTFP act as instruments for the actual variables. The coefficient of ΔTFP was greatly increased and Gap presented a highly significant and positive impact on growth, as initially expected. At the same time, the impact of SC is close to simpler FE estimations, suggesting the consistency of the model and the importance of SC for the determination of growth. The best results were found in the model with intercept (GMM-system) and, particularly, in the model with the lag of the regressand among the regressors, what suggests some level of path-dependence in the growth process (even though the coefficient of $\Delta Prod_{t-1}$ was only significant at 10%).

In summary, the econometric estimation of equation (3.6) revealed the relevance of both structural change process and technological progress to growth. The dependence of trajectory is marked in the process. Moreover, the different dimensions of the productive structure: Gap and sectoral employment shares; effect the product dynamicity in different (even opposite) ways. The tests revealed that the model and specifications can be improved, since the number of instruments weakened the estimations (Hansen) and that the hypothesis of autocorrelation cannot be discarded (indicated both by Arellano-Bond test and residual tests). Specification (viii) shows the impact of using 3-year averages in the estimation of (3.6). Although the coefficients remained stable, the strategy considerably reduced the degrees of freedom and significance of the coefficients. SC is only significant at 10% and ΔTFP not significant at all. A more complete and longer database would be necessary to improve these results.

3.6. Concluding remarks

This chapter sought to discuss the relationship between labour reallocation and growth in manufacturing from a disaggregated perspective. In total, 125 industrial branches in 42 countries were assessed in the period between 1991 and 2009. The first part of the chapter exploited the richness of the database while discussing important hypothesis behind the study: (i) the sectoral composition of the industrial sectors changes over time; and (ii) either the sectoral productivity level or the sectoral productivity growth differ across sectors. Both internal and external productivity cross-country and cross-sector gaps were studied. Regional aggregations were also adopted to exemplify the influence of socio-economic and cultural elements in the relationship of interest.

The exploratory analysis corroborates previous conclusions in the structural literature:

(i) The productivity gap within a country is generally higher than within a sector (McMillan and Rodrik, 2011).

(ii) The productivity gap has increased both across and within sectors and countries (Fagerberg, 2000).

(iii) The structural change process was particularly relevant in the development of Asian countries, with Latin-American countries in the opposite extreme (McMillan and Rodrik, 2011; Roncolato and Kucera, 2014; Ocampo *et al*., 2009; Timmer and de Vries, 2009).

(iv) Productivity growth and employment growth do not walk together in many industrial sectors (Fagerberg, 2000).

The last two sections of the chapter were dedicated to the quantitative measurement of the impact of structural change on growth. Three different methods were employed. The analysis reiterates the relevance of the structural change in growth trajectories. Moreover, it was shown that the sectoral breakdown is perhaps the most important factor determining the power of decomposition exercises to capture the influence of the structural change on growth. This is a fundamental contribution of this chapter, as most of literature does not highlight the impact of the sectoral breakdown in shift-share analyses. As shown, this is especially important in the current stage of development, where structural heterogeneities are increasing within manufacturing.

Other interesting patterns were also uncovered: (i) the structural change impact is negative for most countries, much of it due to the fact that labour tends to move from sectors with high productivity growth rates to sectors with low productivity growth rates, resulting in a negative FR effect; (ii) the importance of the structural change to growth increased in the last decades and the positive effect of PB confirms that labour moves from sectors with low productivity rates (level) to sectors with high productivity rates. Although the Schumpeterian literature discusses the relevance of the diversification process and how this entails growth by the transformation process, until now growth account exercises were not able to empirically confirm this hypothesis.

4. Intra-sectoral reallocation and growth: empirical investigation

4.1. Introduction

The allocation problem originates in production heterogeneities that create divergent trajectories of productivity for different units (firms, sectors, etc). Were these units identical, the re-allocation of factors across them would have no impact on the country's productivity rates and the process of structural change no influence on their growth trajectories.

Following a long established tradition in structural economics, the previous chapter investigated the level of inter-sectoral heterogeneity in manufacturing (i.e., differences in productivity between sectors) and the 'inter-sectoral allocation problem'. This chapter shifts the analytical perspective to the intra-sectoral level and investigates the extent to which the distribution of factors across manufacturing firms influences the aggregate growth rate.

The unit of 'structural heterogeneity' is the firm size. The relationship between firm size, productivity and growth has long roots in economics. Both the neoclassical industrial organisation literature and non-mainstream approaches, such as the Evolutionary school, highlight the importance of the market-structure and population of firm sizes to growth. The intra-sectoral allocation problem, however, has only recently attracted attention[100], mainly by efforts the so-called 'misallocation' literature, which explores the empirical association between the distribution of factors between firms of different sizes and TFP levels[101] (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008). The striking results of this literature have been recognised by a wide audience in economics and influenced a number of policy proposals in recent years (c.f. Jones, 2011; McMillan and Rodrik, 2011). This dissertation claims that a multi-level view of the allocation problem is a necessary step to improve policy recommendations and our understanding of the complexity of the growth phenomena.

[100] This was only possible due to the recent publication of comparable cross-country data at the firm level.

[101] According to these authors, the existence of incentives based on the firm size would be responsible for creating disparities between these firms. The firm heterogeneity makes the intra-sectoral allocation an important issue in growth matters.

For comparability purposes, this chapter replicates last chapter' structure and methods. To substantiate the discussion and justify the approach, next section discusses the premises and the main results of the misallocation literature. The Structural and Demographic Business Statistics (SDBS) database is presented next. The analysis is centred on the empirical investigation of firm size heterogeneity. The productivity trajectories of firms of different size classes are compared and their components decomposed. Counterfactual and shift-share exercises help in the quantitative measurement of the impact of the intra-sectoral reallocation process on growth rates. Finally, the importance of the intra-sectoral structure for growth and income levels is estimated by 2SLS, 2SLS-IV and GMM dynamic panel-data methods.

The main contribution of this chapter lies in its original perspective of the allocation problem, never before explored in at the intra-sectoral level in the non-neoclassical literature. The approach presents also a series of advantages compared to the neoclassical misallocation analysis. Among which: (i) it promotes an exhaustive analysis of the structural heterogeneity at the firm level, something missing in the misallocation approach. Adding to that, (ii) the counterfactual exercise is presented as an alternative that requires weaker hypotheses compared to the original misallocation exercise, being (iii) also free of discretionary parameters requiring calibration. (iv) The shift-share exercise also enables a new perspective of the problem because it does not impose a specific production function to the country. (v) Besides, differently from the misallocation and counterfactual exercises, which only consider the cross-country relative importance of the intra-sectoral allocation to growth, the shift-share shows the actual impact of the first on the latter. Moreover, (vi) both the shift-share and the counterfactual exercises can be compared with the inter-sectoral analysis in the last chapter. Much of the 'within productivity' (PW) gains can actually be explained by the inter-firm reallocation. Finally, (vii) the econometric exercise enables the study of dynamics of the intra-sectoral structural change process and its impact on growth.

4.2. Intra-sectoral allocation and growth: a literature review

Even though studies in the structure-conduct-performance paradigm have long been associating firm-level profitability and growth rates with sectoral patterns of competition, entry, exit and firm size (Ferguson and Ferguson, 1994), it was only recently that the discussion on the intra-sectoral distribution of firm sizes reached a prominent space in the neoclassical growth theory.

Using data on firm size distribution, the so-called 'misallocation' literature (c.f. Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008) – a branch of the industrial organization literature – uses comparative static analysis to assess the potential growth gain generated by a virtual reallocation of factors across and within firms towards an 'ideal' allocation. The latter is defined as the distribution of firm sizes in the most advanced country[102]. The empirical exercise is based upon a monopolistic competition framework in which the allocation of resources across firms depends not only on the firm's level of productivity, but also on the output and capital distortions they face. To the extent that the resource allocation is driven by distortions rather than by the firm's TFP, there will be differences in the marginal revenue across firms. Accordingly, the country (aggregate) TFP is expressed as a function of the misallocation of capital and labour at the firm level and the sectoral TFP. The misallocation is calculated as the distance between the ideal and actual distribution of firms' employment, as the benchmark is the one that maximises productivity and welfare levels (Jones, 2011).

A simple example illustrates the rationale behind the misallocation exercise. Consider, as proposed by Jones (2011), a two-sector economy, a and b, with only one factor, labour (L), which is distributed across these sectors ($\bar{L} = \mathrm{L_a} + \mathrm{L_b}$). The production of each sector good is given by $\mathrm{Q_a} = \mathrm{L_a}$ and $\mathrm{Q_b} = \mathrm{L_b}$. Hence, if one unit of labour can produce either one unit of good a or one unit of b, the only allocative decision in this simple economy is how much labour to employ producing a instead of b. Assuming a Cobb-Douglas (fixed proportions with elasticities assumed to be 1/2) for the economy's production function, the total output (Y) can be written as:

$$Y = {Q_a}^{\frac{1}{2}} {Q_b}^{\frac{1}{2}} \tag{4.1}$$

In which the solution is given in (4.2):

$$Y = A(q)\bar{L} \tag{4.2}$$

where q is the rate of growth of output and $\mathrm{A(q)}$ represents the technological progress function:

$$A(q) = [q(1-q)]^{\frac{1}{2}} \tag{4.3}$$

---

[102] In practical terms, a discretionary distribution function is calibrated with the actual distribution parameters. As the optimal allocation is unknown, the misallocation is measured by comparisons between a benchmark allocation, which is usually defined by the distribution of firm sizes in US sectors (as this economy displays the higher productivity levels and is comparatively undistorted by policies), and the economy under study.

Accordingly, the optimal allocation in this economy is $q^* = 1/2$ and any departure from this allocation will reduce the TFP and, therefore, GDP. In general, the literature assumes no constraints for the maximisation of profits so that the only sources of misallocation are found in market and, especially, policy distortions.

Hsieh and Klenow (2009) claim that the misallocation accounts for 25% to 60% of the industrial TFP differences between China, India and the benchmark (US), respectively. They found an excess of small firms in relation to both the US economy and what would be efficient according to 'workhorse' models of industrial organization with heterogeneous firms (e.g. Melitz, 2003). The 'missing middle', as it was named the relative low number of medium-size firms in the market-structure, is therefore the major cause of differences in aggregate productivity between these countries.

Expanding the methodology, Alfaro, Charlton and Kanczuk (2008), assessed the distribution of the plant size in the industrial sector of 20 million establishments in 79 countries. They found that the model explains 58% of the log variance of income per worker, an impact larger than the 42% average found in the previous model. A related approach is also found in Bartelsman, Haltiwanger and Scarpetta (2009), which decomposed productivity indexes at the industry-level and found evidence of considerable cross-country variation in terms of the 'allocative efficiency'.

The insights of this literature have been acknowledged by both mainstream and non-mainstream audiences (Jones, 2011; McMillan and Rodrik, 2011). The capacity of explanation of the growth phenomena by these studies is noteworthy. Jones (2011, p.3), for instance, claims that the misallocation is "*one of the most important developments of the growth literature in the last decade*". Notwithstanding, the building blocks of the misallocation are liable to much criticism. It is worthwhile emphasising at least two: the discretionary calibration of production functions and the fact that the comparative analysis cannot answer what is the actual impact of the intra-sectoral allocation on growth. It can only to give a clue based on the hypothetical counter-factual generated by cross-country differences. Section 4.5 proposes some alternatives that overcome these difficulties and expand the analysis.

4.3. Data and preliminary exploratory analysis

Considering that there is labour/factor mobility across firms and intra-sectoral prices are homogeneous, either productivity growth or levels must differ across firms for the intra-sectoral structural change to influence the country's growth trajectory.

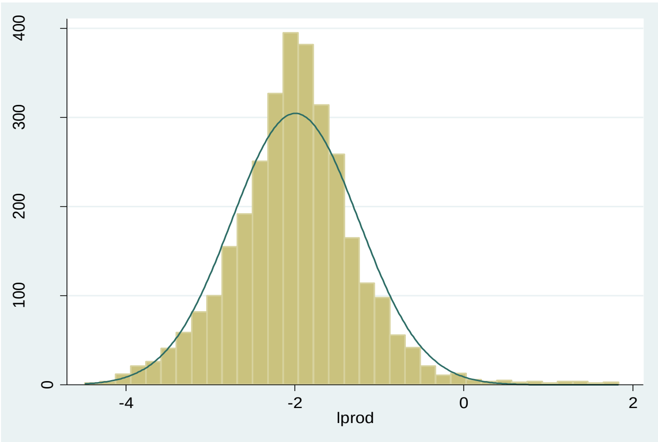
This section introduces the productivity index and investigates the 'intra-sectoral heterogeneity' hypothesis in manufacturing sectors of 35 countries. Data is from the Structural and Demographic Business Statistics (SDBS), which comprises unbalanced annual (1990-2007) information for all OECD countries plus a number of highlighted economies disaggregated in five size classes. The period of analysis and sample selection were determined by the availability of data at the time of the research and a set of robustness constraints. Due to the number of inconsistencies in the firm-level data, the database preparation involved different steps which are detailed in Appendix 2.

Two different analytical perspectives are explored, the World Economy, which aggregates the information for all countries in the sample into their respective sectors at a global scale, and the usual country-perspective. These different angles reveal how the firm size heterogeneity is a relevant problem both across countries and sectors.

4.3.1. The labour productivity index

For comparability purposes (but also because of limitations of the database), this chapter adopts the quotient of the gross output[103] by the number of employees at the size class as the productivity index. Both of these variables are far more complete and balanced across size categories, sectors and countries than the Value Added, Hours Worked by Employees and the Investment series (See Table A2). Alternative measures, such as the value-added by hours worked and TFP are considered in Chapter 6 and shown to be highly correlated with this chapter's index (Spearman rank is above 87%).

Figure 4.1 - Labour productivity histogram: world economy, average (1990-2007)



Source: author's own elaboration (data from the SDBS)

[103] All national currency data were deflated and converted into 2010 constant US dollars using the World Bank PPP conversion factor. Turkey, Japan and South Korea had their units transformed to the millions before conversion.

The next section compares the results for each size class from different analytical perspectives. The average value of the index worldwide is 0.1946 (0.006 standard error). The positive value of 2.392 for the third moment, skewness, says that the distribution is not symmetric, but skewed to the right indicating the relative abundance of outliers in high-productivity sectors, such as oil based ones[104]. Finally, the value of 11.2 for the Kurtosis indicates that the productivity values are more concentrated around the average than the normal distribution. If, however, the information for the outlier sectors is dropped, one cannot reject the null hypothesis that the productivity index follows a log-normal distribution. Figure 4.1 illustrates the average distribution of the logarithm of the index of labour productivity keeping the outliers. The black line represents the normal distribution.

4.3.2. Intra-sectoral heterogeneity: the size classes in the World Economy sample

Other things equal, in an economy with no displaced resources, when labour and/or capital moves from less to more productive firms, the overall product grows. This occurs for both the share of high-productivity firms in total employment and output increases, but also because the productivity of the sector shedding factors might increase, assumed it has a non-unitary elasticity of employment substitution. Therefore, even with full employment and no factors or technology increments, the re-allocation of resources can be a decisive force for growth[105]. An important question still open how important and pervasive is the firm heterogeneity?

Table 4.1 summarises both level and growth statistics on labour productivity and its components for the five firm size classes[106] of the manufacturing sector of the World Economy sample. Small firms (NSC-1) account for an average for 86% of the total number of enterprises. These employ circa 17% of the manufacturing labour worldwide, but contribute only with 7.32% of the total output. At the opposite end of the spectrum, large firms (NSC-5) were only 0.4% of the total number of enterprises, but accounted for 35% of the employment and 53% of the total output. The annual average growth rate, reported in the square brackets, also reveal important and distinctive patterns across size classes. The class of small firms presents the highest growth rates for both employment (12%) and output (10%). This is in contrast with NSC-5 firms, which declined in terms of both employment (-1%) and output (-1.3%) in the period.

[104] When this sector is excluded from the sample, the skewness approximates to zero.
[105] The conclusion remains if any of the assumptions are relaxed.
[106] There are several hypotheses involved in such a simplification, but given the log-normal distribution of the variables cannot be rejected, the averages presented tend to represent the whole diversity of goods, firms and sectors in the sample.

The firm size heterogeneity is even clearer when analysing the productivity index. While productivity grows monotonically with size, its growth rate varies negatively with it. Furthermore, the standard deviation (a measure of the internal size class heterogeneity) decreases as a percentage of the average value of productivity. NSC-5 firms are, on average, 3.2 times more productive than NSC-1 firms. Even though the latter grows at a much faster pace (5.7% against 2.7%), the dynamics of the internal heterogeneity indicates that this is not uniform across the firms in the class, but rather concentrated in a smaller group of more dynamic firms. Large firms, besides having a more uniform level of productivity, also grow more homogeneously.

Table 4.1 – Size class productivity and basic shares for the world economy: average (1990-2007)

Size category	Share of total enterprises	Average labour productivity	Internal heterogeneity**	Employment share	Output share
NSC-1	85.80% [50%]	0.087 [5%]	20.16% [26%]	16.80% [12%]	7.32% [10%]
NSC-2	7.38% [19%]	0.113 [2%]	15.19% [5%]	9.62% [0.5%]	5.71% [1%]
NSC-3	4.29% [27%]	0.142 [3%]	14.14% [3%]	14.47% [-0.2%]	10.81% [0.8%]
NSC-4	2.11% [33%]	0.189 [3%]	11.56% [5%]	24.07% [2%]	23.93% [3.5%]
NSC-5	0.42% [35%]	0.279 [3%]	13.06% [3%]	35.04% [-1%]	52.23% [-1.3%]

Notes: Growth rates in brackets. **Cross-sectors standard deviation as percentage of the productivity.
Source: author's own elaboration (data from the SDBS)

The growth rates of the variables disclose valuable information on the differences in the dynamics of both demand and technology across size classes. From the last two columns in Table 4.1, one can infer that an important share of the improvement in the NSC-1 productivity rate is due to the rapid increase of demand for the goods produced by these companies (the output of small firms grew at a much faster pace compared with other classes). However, the labour input increased at an even faster pace, indicating a lower technological level. For all other classes the growth of output exceeded employment growth, confirming the better technological position of larger firms.

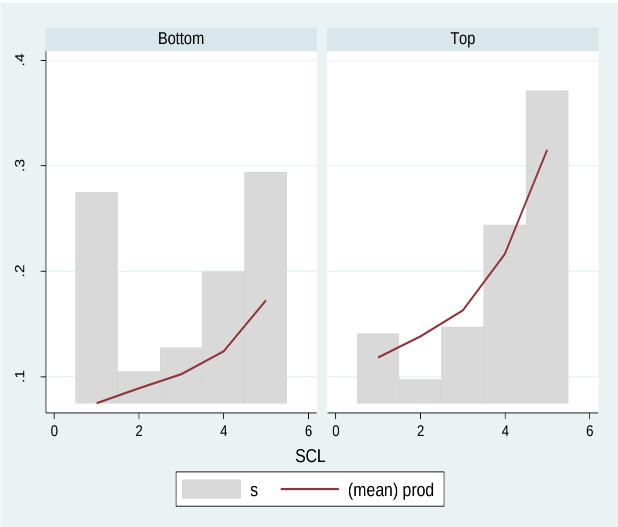
This confirms that productivity levels and growth rates are correlated with firm size. Moreover, the gap is far from equalisation as small firms display, on average, only 45% of the productivity of large firms. Such level of heterogeneity creates scope for the intra-sectoral structural change to influence sectoral and country growth rates.

4.3.3. Cross-country patterns of intra-sectoral allocation

Table A4 in the Appendix presents the productivity index, employment shares and output shares for each of the five size classes and countries in the sample. The internal gap, represented by the standard deviation of the index across the size classes is also displayed. Productivity increases with firm size for the vast majority of the countries in the sample, being this correlation even stronger in more advanced countries. Also, the more developed the country, the higher the productivity gap between small and large firms. In Japan, the country with highest overall level of manufacturing productivity, the productivity of NSC-1 companies is only 20% of NSC-5 companies. In contrast, in Latvia, the average NSC-1 firm's productivity is around 82% of the NSC-5 firm.

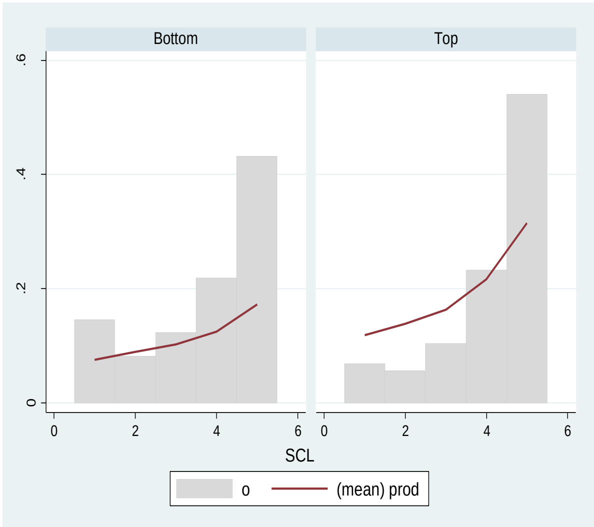
The employment and output shares (L_s and Q_s) also follow a common pattern in the vast majority of the countries of the sample. On average, circa 22% of the total employment is in NSC-1 firms and 32% in NSC-5. These account, respectively, for 14.5% and 43% of total output. Only for large firms (NSC-5), the output share exceeds the employment share. More importantly, countries peaking on the productivity index have the highest shares of both output and employment in NSC-5 firms. This is illustrated in Figures 4.2 and 4.3 below.

Figure 4.2 - Employment allocation by firm class



Notes: Horizontal axis = size classes (NSC-1 to NSC-5);
Vertical axis = labour employment share
Source: author's own elaboration (data from the SDBS)

Figure 4.3 - Output allocation by firm class



Notes: Horizontal axis = size classes (NSC-1 to NSC-5);
Vertical axis = output share
Source: author's own elaboration (data from the SDBS)

The figures present the cross-country average distribution of labour and output by firm size class (bars) and the productivity of each class (line). The 50% least productive (bottom half) countries (at the left side diagrams) are contrasted with the top half (right side diagrams). The conclusion is striking: not only are the advanced countries more productive in each class, as they also allocate less of their labour and output in less productive business (NSC1-2) and more on the more productive (NSC4-5). While little more than 13% of the total employment is allocated in small firms in the high-productivity countries, countries scoring worse on productivity employ 28% of their labour in NSC-1 firms.

4.4. Productivity decomposition

Last section revealed a significant level of heterogeneity across firm size classes and discernible cross-country patterns of intra-sectoral specialisation. As highlighted in section 4.3, the cross-size classes divergences in the productivity measure and components is a significant indicator of the potential influence of the intra-sectoral re-allocation on the aggregate growth rate. This section assesses the relative importance of changes in the market-structure in the productivity index. Two complementary exercises are discussed below: the counterfactual, which is presented as a simpler alternative to the original misallocation exercise, and the shift-share.

4.4.1. Counterfactual analysis: an alternative misallocation exercise

Both the misallocation exercises and the counterfactual analysis introduced in the last chapter are based on static comparative analysis. They assess the impact on the productivity index of a hypothetical reallocation of factors. That is, to impose a specific distribution of firm sizes, based on a pre-defined benchmark country, and then estimating the new level of productivity and output.

The original misallocation exercise requires the calibration of a production function assuming distinct levels of distortions and heterogeneous firms (Hsieh and Klenow, 2009). The counterfactual exercise of McMillan and Rodrik's (2011) presents several advantages, including the fact that it is a more intuitive exercise, with no calibrations and pre-assumed distributions and models, but especially for not assuming a production function and using its residue as TFP[107].

This section adapts McMillan and Rodrik's approach to the analysis of the intra-sectoral analytical level. The exercise consists in promoting a virtual structural change in a country towards a

[107] The shortcomings of a production function are extensively treated in the heterodox literature. Even though the aggregation problem is at the core of the criticism, one aspect in the concept has received much attention recently: the use of the production function residual as the total factor productivity (TFP). As Felipe and McCombie (2006, p.283) argue, "*the estimates of total factor productivity growth resulting from growth accounting performed with aggregate monetary data are not equivalent to the true rate of technological progress implied by the micro-data. This suggests that results from the orthodox growth accounting approach may be very misleading*".

benchmark productive structure (country x), while holding constant the actual levels of firm size class productivity and vice-versa. The total aggregate productivity of labour ($prod$) in any country y is then measured before (t0) and after (t1) the structural change takes place. Formally:

$$prod_b = prod_{y,t1} - prod_{y,t0} \qquad (4.4)$$

$$prod_w = prod_x - prod_{y,t1} \qquad (4.5)$$

Where $prod_b$ is the 'productivity between' and $prod_w$ the 'productivity within'. $prod_x$ is the productivity in the benchmark country x. Both $prod_b$ and $prod_w$ can be positive, negative or null. The sum ($prod_b + prod_w$) gives country y's actual productivity growth rate. Equation (4.4) gives the potential productivity 'gain' due to the intra-sectoral reallocation of factors, and equation (4.5) the potential productivity 'gain' due to the adoption of the best production methods and increases in factors quantity.

For the inter-sectoral composition not to influence the results, the country production is aggregated in the five size classes considering no specific sectoral distributions[108]. The results of the application of the method are presented below. The average intra-sectoral composition of US, Japan, Korea and Germany and a composite of these were tested as benchmark[109] and all produced similar results.

Table 4.2 presents the results for Germany as benchmark. PB is the hypothetical productivity rate of the country if its distribution of labour was the same found in Germany. This assumes that the actual levels of productivity in each country and size class remain constant. PW, in contrast, is the productivity rate if the country under consideration presented the same level of productivity for each size class found in the benchmark, keeping the country's intra-sectoral distribution of labour. Countries are displayed in a decreasing order of the gain (potential) with the structural change (ΔPB).

The results are striking: only four countries would experience no gains with such reallocation of labour. The un-weighted average productivity index worldwide, highlighted in the last line of Table

[108] This distinction is not made in misallocation studies. Thus, part of the alleged intra-sectoral effect found in these studies can be sourced in the inter-sectoral allocation.

[109] The choice for these countries as benchmark is justified by the high overall productivity rates in these economies.

4.2, would increase 14.5 percentage points – reaching an average productivity rate of 0.19 against the original 0.166 – if the intra-sectoral allocation of Germany was replicated in all other countries. The gain with the counterfactual level of productivity would be much smaller (0.011 in level or 6.6%). The inter-firm re-allocation of labour would result in an average gain of 11.7% in total productivity, with countries such as Turkey, Italy and Spain increasing their respective levels of productivity in more than 70%, 43% and 40%, respectively. The gain with technical change (ΔPW) had a much higher variance both in values as well as in range.

Table 4.2 - Country misallocation: average (1990-2007)

Country	Productivity index	PB*	PW**	Δ PB	Δ PW
Turkey	0.101	0.172	0.143	70.91%	42.14%
Italy	0.203	0.289	0.148	42.10%	-27.19%
Spain	0.189	0.266	0.155	40.47%	-17.94%
Portugal	0.111	0.155	0.150	39.74%	34.98%
Greece	0.158	0.203	0.163	28.46%	3.16%
Belgium	0.269	0.324	0.170	20.28%	-36.97%
Japan	0.255	0.304	0.179	19.40%	-29.78%
Netherlands	0.238	0.283	0.168	19.19%	-29.26%
Korea	0.261	0.304	0.182	16.18%	-30.32%
Poland	0.131	0.151	0.178	14.90%	35.48%
Hungary	0.133	0.151	0.183	14.01%	38.13%
Czech Republic	0.129	0.147	0.181	13.49%	39.65%
Israel	0.157	0.176	0.178	12.07%	13.54%
Cyprus	0.100	0.112	0.143	12.02%	43.36%
Austria	0.183	0.205	0.180	11.94%	-1.37%
France	0.211	0.236	0.182	11.85%	-13.98%
Norway	0.188	0.210	0.171	11.62%	-9.00%
United Kingdom	0.197	0.218	0.182	10.70%	-7.40%
Denmark	0.144	0.158	0.177	9.58%	22.40%
Bulgaria	0.075	0.082	0.189	9.50%	151.11%
Sweden	0.198	0.217	0.185	9.43%	-6.73%
Ireland	0.288	0.315	0.184	9.04%	-36.04%
Lithuania	0.194	0.211	0.187	8.37%	-3.85%
Finland	0.228	0.244	0.190	6.60%	-16.84%
Latvia	0.078	0.083	0.170	6.15%	116.24%
Estonia	0.087	0.092	0.166	5.91%	90.42%
Slovenia	0.142	0.149	0.191	4.82%	35.03%
Slovak Republic	0.104	0.106	0.206	1.68%	98.36%
Germany	**0.204**	**0.204**	**0.204**	**0.00%**	**0.00%**
Romania	0.056	0.055	0.215	-1.67%	284.24%
Australia	0.112	0.110	0.157	-1.69%	40.18%
Luxembourg	0.181	0.157	0.198	-13.73%	9.23%
Malta	0.095	0.068	0.187	-28.30%	97.57%
Global average/median**	**0.166**	**0.190**	**0.177**	**11.733%****	**6.193%****

Notes: * Hypothetical productivity should the country displayed the same labour allocation of the benchmark country. ** Hypothetical productivity should the country presented the same levels of productivity for each size class as the benchmark country.
Source: author's own elaboration (data from the SDBS)

The correlation between the productivity index and PB is of 95%. The correlation between the former and PW is much smaller, only 7%. The relationship between PW and PB was investigated by two different rank correlation tests. The Spearman's and Kendall's rank correlation coefficients are negative, -0.14 and -0.09, respectively. The probability of the rejection of the null hypothesis that both are independent was 0.42% in both tests. The small value of the tests indicate that their determinants are distinct, having each, probably, little interference on the other. Nevertheless, the gains with the process of structural change and technical change are likely to be in opposite directions.

4.4.2. Productivity decomposition

The exercise in the previous section shows the potential gain with the reallocation of labour following a pre-defined intra-sectoral distribution of firm sizes. This section goes a step further and decomposes the actual productivity growth into its technological and intra-sectoral composition components using the shift-share exercise detailed in the last chapter. Although it has been heavily criticised[110], the technique is widely adopted in the literature for it enables the direct measurement of the relative importance of structural change to growth[111]. Consider therefore that:

$$prod = \frac{Q}{L} = \frac{\sum Q_i}{\sum L_i} = \sum \left(\frac{Q_i}{L_i} \times \frac{L}{\sum L_i} \right) \qquad (4.7)$$

where Q is the value added (or output) and L the labour input. There are no industries and the subscript i indexes the size classes. Defining the labour productivity in sector i as $prod_i = \frac{Q_i}{L_i}$ and the share of sector i in total employment as $S_i = \frac{L_i}{\sum L_i}$, then (3.1) can be rewritten as $prod = \sum prod_i S_i$. Knowing that Δ represents the difference between the actual and previous period, and using growth rates it becomes:

$$\Delta prod = \sum \left(\frac{prod_{it-1} \Delta S_i}{prod_{t-1}} + \frac{\Delta prod_i \Delta S_i}{prod_{t-1}} + \frac{S_{it-1} \Delta prod_i}{prod_{t-1}} \right) \qquad (4.8)$$

The first two terms on the right side give the 'productivity between' (PB), where the first represents the contribution of changes in the allocation of labour between firm size classes to productivity

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110 See Chapter 3 for a review of the method.

111 To my knowledge, this exercise has never been applied at the intra-sectoral analytical level, constituting an important contribution of this chapter.

growth (hereby SC for it conveys the structural change effect). SC is positive when the country shifts labour to higher productivity (generally larger) firms. The second term is a frictional term, hereby FR, and represents the interaction between changes in productivity in individual firms and changes in the allocation of labour across size classes. It is positive when the country shifts labour towards firms with higher productivity growth rates. Finally, the last term (PW, for it represents the productivity within) measures the contribution of the growth of the internal productivity of each size class (Fagerberg, 2000).
Table 4.3 summarises the results of the application of the above method to the SDBS country sample. It is worth emphasising that the period of analysis and number of years varies from country to country, which might explain part of the divergent results. The figure shows both the actual and relative contribution of the element to the average annual growth rate[112]. Although the average cross-sectional component is positive (highlighted in the last line of the table), either FR and/or SC were negative in many countries. This suggests that labour shifts in the period were directed to firms with lower productivity growth rates, in the first case, and from firms of high to firms of low productivity levels, in the second case (Fagerberg, 2000).

On average, the between effect accounted for 31% of the annual average productivity growth, with improvements in techniques accounting for the remaining 69%. The relative participation of each SC and PW presented a huge variance across countries. For instance, SC explains 56% of Malta's average growth rate of productivity. In contrast, PW accounted for almost 87% of productivity average annual growth rate of Latvia. More importantly, it is interesting to note that countries for which SC was smaller are amongst the less developed in the sample, followed by some of the most advanced countries, with intermediate-income countries scoring higher in PW, though some exceptions are also found.

The comparison with last chapter's results is revealing. While the inter-sectoral reallocation (SC) was especially important for the growth of less developed countries, this cannot be asserted for the intra-sectoral reallocation. This shows that the allocation problem has distinct causes at each level of analysis. Advanced countries still have a considerable potential growth to enjoy from a re-distribution of resources between firms, even though a re-distribution of these across sectors can be

112 In contrast with previous applications, instead of choosing two points in the country series to decompose the productivity growth in the period, the exercise is done yearly. The average results displayed are believed to be more consistent as they smooth year-specific changes.

of lesser importance. Corroborating this conclusion is the fact that the temporal variability of PW and PB, in all cases, is higher than the cross-section variability.

Table 4.3 - Productivity growth decomposition: shift-share by country

Country	Annual average productivity growth*	Prod between (PB)			Prod within (PW)	
		Value*		Share**	Value*	Share**
		Prod SC	Prod FR			
Austria	1.09%	0.0029	0.0001	38.99%	0.0081	61.01%
Belgium	1.05%	0.0032	-0.0006	34.13%	0.0073	65.87%
Bulgaria	2.62%	-0.0024	-0.0003	7.53%	0.0286	92.47%
Cyprus	2.02%	0.0063	0.0007	26.31%	0.0139	73.69%
Czech Republic	1.03%	-0.0011	-0.0008	34.67%	0.0115	65.33%
Denmark	0.76%	0.0013	0.0002	25.77%	0.0063	74.23%
Estonia	0.58%	0.0005	-0.0028	45.06%	0.0052	54.94%
Finland	1.25%	0.0021	0.0001	25.06%	0.0104	74.94%
France	0.82%	0.0015	-0.0004	34.79%	0.0068	65.21%
Germany	0.90%	-0.0015	-0.0040	27.48%	0.0105	72.52%
Greece	1.02%	0.0068	0.0012	44.43%	0.0034	55.57%
Hungary	1.95%	-0.0029	-0.0030	47.49%	0.0224	52.51%
Ireland	0.46%	-0.0001	0.0033	24.32%	0.0047	75.68%
Israel	4.51%	0.0130	0.0119	17.52%	0.0321	82.48%
Italy	0.53%	0.0012	0.0003	43.29%	0.0041	56.71%
Japan	0.51%	-0.0004	0.0000	22.01%	0.0055	77.99%
Korea	1.52%	-0.0041	-0.0003	22.68%	0.0192	77.32%
Latvia	0.58%	-0.0011	-0.0032	13.27%	0.0069	86.73%
Lithuania	1.89%	0.0008	0.0032	19.37%	0.0181	80.63%
Luxembourg	9.19%	0.0997	0.0058	33.81%	-0.0078	66.19%
Malta	-1.99%	-0.0298	0.0004	56.08%	0.0099	43.92%
Mexico	4.33%	0.0227	0.0199	16.89%	0.0206	83.11%
Netherlands	2.20%	0.0017	0.0039	26.67%	0.0203	73.33%
Norway	0.82%	-0.0030	-0.0006	34.96%	0.0112	65.04%
Poland	0.52%	0.0023	0.0001	48.02%	0.0029	51.98%
Portugal	0.93%	0.0045	0.0012	26.62%	0.0049	73.38%
Romania	2.22%	-0.0035	-0.0006	17.54%	0.0257	82.46%
Slovak Republic	3.51%	0.0021	0.0019	4.38%	0.0330	95.62%
Slovenia	1.22%	0.0022	-0.0016	38.13%	0.0100	61.87%
Spain	0.49%	0.0002	0.0008	46.97%	0.0047	53.03%
Sweden	0.52%	0.0009	0.0009	50.38%	0.0043	49.62%
Turkey	-0.06%	-0.0022	0.0004	39.39%	0.0016	60.61%
United Kingdom	0.45%	-0.0002	-0.0002	31.37%	0.0047	68.63%
AVERAGE	**1.50%**	**0.0037**	**0.0011**	**31.07%**	**0.0112**	**68.93%**

Notes: * All values presented are averages of non-missing values of the variables by country. ** For PB and PW can assume positive and negative values, the shares represent the weight of the term in the sum of absolute values for PB and PW.
Source: author's own elaboration

Due to the lack of studies on the topic, these results stand alone in favour of the importance of the intra-sectoral allocation problem in growth considerations. These are, however, consistent with the findings in the misallocation literature highlighted in section 4.2.

4.5. Econometric analysis

The conclusions in the previous sections are based on descriptive exercises and thus cannot be generalised over periods and/or units. This would require knowing the distributive characteristics of the variables and the estimation of a probabilistic relationship, which can be causal or not[113]. This section estimates the impact of changes in the structural elements on productivity growth.

According to the view defended in this chapter, productivity growth is explained either by technical change and/or changes in the allocation of inputs (see Equation 4.8). Accordingly, the multi-sectoral econometric growth model can be represented by:

$$\Delta Prod_{i,t} = \propto_0 + \propto_1 SC_{i,t} + \propto_2 \Delta TFP_{i,t} + \emptyset X_{i,t} + u_{i,t} \qquad (4.9)$$

Where the subscripts i and t refer to country and year, respectively. $\Delta Prod$ represents the growth of productivity, SC the process of structural change and ΔTFP measures the technical change. Finally, $X_{i,t}$ is a set of controls, and $u_{i,t}$ the error term.

As discussed, the market-structure interacts in a rich way with the process of technological progress to determine the level of product. In fact, there are several dimensions of the structural element, among which: the change in the average firm size (SC), the level of structural heterogeneity (Gap), as this works as a conditioning for the impact of SC on growth[114], and the actual level of concentration of the market-structure (NSC5). One may also include the interaction between SC and technological progress as a necessary dimension, given Equation (4.8).

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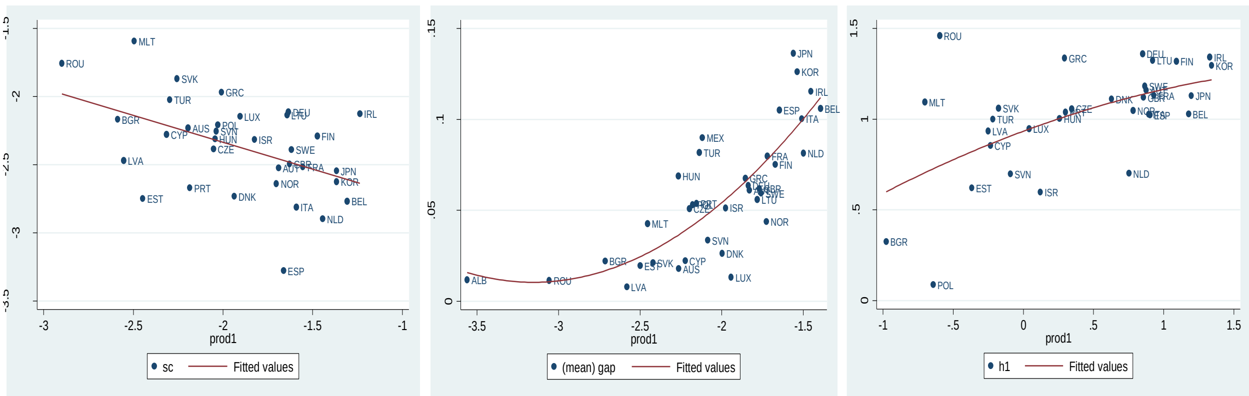
[113] The key for a causal econometric estimation is assuring the randomness of the variables in the reduced model. However, as aggregated measures are used in this specific study, it is impractical to assume that all sources of disturbance are controlled for. Fortunately, the econometric literature has developed a number of different methods to circumvent the most common problems of macro estimations. Different models and methods are adopted in this section. The consistency of the results are generally accepted as a good indicator of the fit of the model.

[114] Should the production units be homogeneous, the structural change per se would have no impact on the level of productivity.

Figures 4.4, 4.5 and 4.6 illustrate the relationship between three different dimensions of the market-structure with the productivity index: (i) SC, which is proxied by the standard deviation of the composition of size classes; (ii) Gap, represented by the log difference of productivity index for the highest and lowest productivity size class; and (iii) the concentration of the market-structure (HH), measured by a traditional Hirshman-Herfindhal index. While SC is negatively correlated with $prod$, both HH and gap are positively correlated with the log of the productivity index. The relationship follows an exponential path in the first and a logarithmic in the second. These differences reinforce the importance of carefully picking the variables to represent the dimension of interest of the relationship[115]. The cross-country trajectory of gap informs us that the productivity disparity between large and small firms grows continually with the country's level of development, represented by the log-level of labour productivity. Although HH also increases with productivity level, indicating that countries concentrate their output in larger firms in the development trajectory, this process decelerate with the growth of Prod.

Figure 4.4, 4.4, 4.5 - Per capita productivity and intra-sectoral change measures: SC, gap and HH* by country



Notes: *HH = h1 = Hirshman-Herfindhal index (log). Horizontal axis = prod1 = log of the productivity index. SC is the rate of change of the intra-sectoral composition. Gap is the log-difference between the NSC with the highest productivity level and the lowest.
Source: author's own elaboration

Since these appear to influence the product in a different way, in some cases even in opposite directions, one may choose to explicitly consider these different dimensions of the change in the market-structure when estimating (4.9).

[115] Different moments of the distribution of firm sizes were also tested, but these appear to have more overlapping characteristics between themselves than the variables above.

A few other problems require attention when estimating (4.9). Firstly, the explanatory variables are not necessarily randomly distributed, but interact with one another and may also channel the effect of other omitted variables in the estimation. The explanatory may also interact with one another, as showed by FR in equation (4.8)[116]. The simultaneity of the explanatory variables requires suitable estimation strategies in order for the results to be consistent. The problem can be aggravated by measurement problems, for these elements are not properly observable.

Table 4.4 presents the results of the estimation of (4.9) through a fixed-effects model[117]. See Appendix 3 for a discussion on panel data methods and its limitations. The standard errors were corrected by using the method of robust variance of White. Macroeconomic, institutional and structural variables are included in the group of controls. This comprises[118]: (i) country population; (ii) share of exports in the GDP (level of openness); (iii) decade and income group dummies; (iv) investment; and (v) human capital level.

Table 4.4 – Intra-sectoral structural change and growth: cross country panel data estimation (1990-2007)

Variable	Fixed-Effects (FE)			GMM-SYS Small
ΔProd	(i)	(ii)	(iii)	(iv)
SC	-0.0009***	-0.0007***	0.0008*	-0.0003*
ΔTFP	0.1892		-0.1109	0.2584*
Log(Gap)		0.0824***	0.3206***	0.3571**
FR			-0.0104	
ΔNSC5			0.4638***	0.3183***
Constant	0.0517***	0.2840***	-0.9422***	0.0156
Observations	290	290	146	285
R^2	0.008	0.0807	0.6591	
Corr (u, b)	0.0065	-0.755	0.4326	
F	522	698	470	177
Sargan				192.525
Hansen				28.183

Notes: * p<.1; ** p<.05; *** p<.01

Source: author's own elaboration (data from the SDBS)

[116] In a broader sense, since technology and the scope for technical change varies across firms, it will determine structural change in time. On the other way around, SC also influences ΔTPF, as the heterogeneous productive units may have different technological trajectories which are endogenously determined (Kaldor, 1970).

[117] The results for the Hausman, Breusch and Pagan test indicate that one cannot reject the hypothesis that individual specific effects are potentially correlated with regressors, justifying the choice for the model with fixed-effects.

[118] All the control variables were drawn from the Penn World Table 9.0.

Overall, the variability of the average firm size (SC) appears to affect negatively productivity growth. The results are statistically significant and consistent across specifications and country groups, even though the impact is close to zero. None of the controls and regional dummies was significant. Their inclusion would cause either an increase of the heteroskedasticity and a reduction of the F-statistic and R^2 in the models.

The important aspect contained in Table 4.4, however, is the unquestionable importance of the other market-structure-related variables to growth. The key element in this respect was the growth of the share of NSC-5 firms in total employment (ΔNSC5). This variable alone explains more than 55% of the ΔProd, as evidenced in the R^2 of model (iii). The Gap was also highly significant. 1% increase in Gap or ΔNSC5 cause an increment of 0.32 to 0.46 in the productivity growth. The growth of TFP was only significant in the GMM estimation, perhaps because the endogeneity of the variable require a more advanced identification strategy. FR was not significant in none of the specifications and thus only illustrated in (iii). Its inclusion, however, cause a change in the signal of SC, what illustrated how the market-structure variables are correlated and channel the impact of the omitted element.

Since Fixed-effects are considered poor instruments in the presence of endogeneity, a more accurate estimate of the relationship is obtained with the use of the 'Generalized Method of Moments' (GMM). Two different dynamic models were tested: the System-GMM and Diff-GMM (Cameron and Trivedi, 2005). The first model presented the best statistical fit[119] and is illustrated in column (iv).

To see the accumulated impact of the market-structure in the productivity level and not change, consider the following model, which differentiates from (4.9) for using log-levels instead of growth rates of the variables:

$$Prod_{i,t} = \propto_0 + \propto_1 SC_{i,t} + \propto_2 TFP_{i,t} + \emptyset X_{i,t} + u_{i,t} \qquad (4.10)$$

That is, the productivity level is explained by the market-structure level elements (SC) and the internal level of capabilities accumulated represented by TFP. Table 4.5 presents the results of the

[119] Sargan, Hansen and Arellano-Bond tests reveal the good adjustment of the model.

estimation of (4.10). The same general patterns observed in Table 4.4 remain, with the exception that the log-level of TFP is highly significant in all models. SC has a significant but very small negative impact on the log-level of productivity (lags of it also showed a small effect), while the Gap presents a significant and positive impact, comparable to the TFP. The highlight is again the NCS-5 share in total employment. The variable alone increases the R^2 of the estimation to almost 60%, confirming the key importance of the firm size in the country's level of productivity.

Despite the specification and method, the conclusion that the firm size distribution does have a role on the process of growth remains. The intra-sectoral structural change effect is not important as the inter-sectoral structural change, as highlighted in Chapter 3, but the firm size and level of productivity heterogeneity are, unquestionably, the drivers of the intra-sectoral process of growth.

Table 4.5 – Market-structure and productivity levels: cross country panel data estimation (1990-2007)

Variable	Fixed-Effects (FE)		GMM-SYS Small	GMM-SYS Orthog
Log(Prod)	(i)	(ii)	(iii)	(iv)
SC	-0.0008***	0.0003	-0.0007**	-0.0015*
Log(TFP)	0.8482***		0.5625***	0.3846*
FR		-0.0092	-0.0042	-0.0067
Log(Gap)		0.3670***	0.4162***	0.4677***
Log(NSC5)		0.6107***	0.4923***	0.6135***
Constant	-1.5966***	-0.0101	0.1553	0.3911
Observations	290	147	147	147
R2	0.0753	0.7279		
Corr (u, b)	0.1188	0.3252		
F	522.0043	7.10E+03	61.4905	22.8023
Sargan			677.7037	538.5453
Hansen			21.4072	27.4457

Notes: * p<.1; ** p<.05; *** p<.01

Source: author's own elaboration (data from the SDBS)

4.6. Concluding remarks

This chapter concerned the empirical relevance of the inter-firm [labour] allocation in growth trajectories. Confirming Bartelsman, Haltiwanger and Scarpetta (2009), the analysis revealed a considerable cross-country variation in terms of allocative efficiency. Three different approaches were employed for the investigation of the potential, actual and relative impact of changes in the firm size distribution on productivity.

(i) The shift-share analysis showed that the intra-sectoral allocation accounted for 17% to 56% of the productivity growth for the sample of 35 countries in the period between 1990 and 2007.

(ii) The counterfactual exercise pointed potential high gains with different allocations. Up to 71% of the difference between Germany and Turkey's productivity levels, for instance, can be explained by the 'misallocation' of labour employment. The results are comparable to Hsieh and Klenow (2009) – for which the misallocation accounted for 25% to 60% of the industrial TFP difference between China, India and US – and Alfaro, Charlton and Kanczuk (2008), which found that the phenomenon explains an average of 58% of the TFP difference worldwide.

(iii) The econometric exercise showed that the market-structure interacts in a rich way with the technological progress element to determine both the level and growth rate of productivity. Each dimension of the first, such as internal gap, the level of concentration and the variance of firm sizes affect growth in a different way. The level of market concentration, however, seems to work as the engine of the intra-sectoral growth process.

Comparing the above with the inter-sectoral analysis in Chapter 3, one may realise an important difference: Whereas in the inter-sectoral analytical level the structural change accounts for circa one-third of the productivity growth, at the intra-sectoral level the role is inverted. The market-structure is the main determinant of productivity, even though the key variable is not the change in the average firm size, but the concentration of the market. Yet, in both analytical levels, the level of productivity heterogeneity is bigger the more developed the country, an indication of the importance of the [multilevel] structural variety for growth (as emphasised in Chapter 1). The next chapter investigates the foundations of the productivity heterogeneity across firms. This is a fundamental step to understand how and why the intra-sectoral allocation influences growth.

5. Firm size and the micro-foundations of the intra-sectoral development process

5.1. Introduction

This chapter revisits the Evolutionary perspective on the relationship between firm size, innovation and growth to explain the empirical patterns recently unearthed by the misallocation literature. According to the seminal works in the Evolutionary tradition, both the process of inter-firm competition for innovation (Schumpeterian competition) and returns to scale associated with firm size (Schumpeterian hypothesis) make the concentration of the market-structure a necessary step to technological progress.

The contribution of this chapter is threefold. First, it offers an explanation for the long-term and dynamic impact of the intra-sectoral allocation on growth, providing much needed foundations for the misallocation findings. Secondly, the original perspective of the analysis (intra-sectoral) enables the investigation and uncovering of important meso-foundations of the development process[120], such as the actual role of the firm size and market-structure for technological progress. Finally, by empirically assessing the micro-foundations of the firm development, the chapter ratifies the importance of the firm size to the process of technological progress and shows how the current Evolutionary emphasis on categorising technological regimes and sectoral patterns of innovation can be misleading.

The next section introduces Nelson and Winter's (1982) seminal growth model and discusses a rule for making the process of technological progress endogenous on the firm size and sectoral characteristics. The approach aims at adapting the seminal model for the analysis of the development traverse of manufacturing sectors. Section 5.3 assesses empirically the assumptions of the model. The results indicate that the relationship between firm size, innovation and growth is non-linear. This explains the controversy in the empirical literature on the Schumpeterian hypothesis. The final section reiterates the contributions of the approach and introduces the

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[120] The pursuit of the meso-foundations of the growth process has been an important drive of the recent Evolutionary literature (Dopfer, Foster and Potts, 2004; Foster, 2011; Allen, 2014). It is argued that it could enable a macro analytical analysis of the growth process, in place of simulation and agent-based approaches that dominate this school.

discussion of the unaccounted role of demand in the intra-sectoral development trajectory, which is further detailed in Chapters 6 and 9.

5.2. A model of industrial development

This section discusses the adaptation of Nelson and Winter's (1982) growth model for the representation of the intra-sectoral process of technological progress. Focusing on the collective micro behaviour, the approach eliminates the excessive complications brought by the stochastic nature of the firm-level process of innovation. Ultimately, the choice for meso- instead of micro-foundations enables the pursuit of an analytical response for the growth problem, as discussed in Chapter 6.

In the following, a number of simplifying hypotheses are made[121]: i) Innovation is broadly assumed as any form of investment expenditure that results in the accumulation of capital by the firm; ii) the path of technological progress is determined at the sectoral level, i.e., by the knowledge base governing the sector[122]; iii) within a sector, the only source of technological variability comes from the actual stock of capital, which also gives the scale of production. As a corollary of the above propositions, the firm's level of innovation is represented by its size or, in other words, the current stock of capital gives the position of the firm in the path of technological progress.

5.2.1. The microfoundations of the sectoral growth

Assume that the output of sector i at any time is given by the stock of capital and labour employed in a specific fashion. If $q = \frac{Q}{L}$ represents the output per worker, $k = \frac{K}{L}$ the capital-labour ratio[123], and $A > 0$ the technical coefficient, the output per unit of labour can be portrayed as in the classical AK endogenous growth model (Romer, 1990):

$$q_i = Ak \qquad (5.1)$$

[121] These are relaxed in the next chapter.

[122] Notice that this does not mean that technological progress is exogenous. In fact, the firm size is showed to endogenously determine the process of technical change. The approach sets, however, boundaries to the impact of firm size on growth. See Chapter 1.

[123] The letter k, therefore, denotes both physical and human capital.

The growth rate of labour productivity ($\dot{q}$) – and thus the capital/labour ratio – will depend on the investment rate ($\dot{k}$), which responds positively to the level of technology (A) and to the savings rate (s), and negatively to the growth of labour employment (n) and to the depreciation rate (δ):

$$\dot{q} = \dot{k} = sA - (n + \delta) \qquad (5.2)$$

Nevertheless, since δ is exogenous and, in a monetary economy, s (ex-post) is determined by investment (ex-ante), then it is possible to conclude that $\dot{q}$ is ultimately constrained by the nature of the process of technical change[124] (A).

Arguably, rather than relying on an exogenous technical coefficient (A), an Evolutionary model must provide a more detailed representation of the complex and varied process of technological progress. This can be implemented either explicitly, by modelling the process of technical change itself, or, more simply, by describing the impact of innovation on the firm's profit/cost functions[125]. Although simpler, the latter does not free the analysis from some complications in the representation of innovation. Albeit dependent of the level of spendings on search activities and the firm's technological choices, innovation is usually defined as a disruptive, non-linear and stochastic process (Nelson and Winter, 1982). Even within the technical boundaries set by the knowledge base governing the sector, for an individual firm there are countless alternative strategies for innovation and even more different outcomes[126]. A usual solution in the literature is to assume different rates of return and success for each innovation strategy[127]. Were each of these parameters and odds known, the outcome of any strategy could be represented by a discount factor in the firm's cost/profit function, e.g.:

$$\pi_i = PA_j - c - r_j \qquad (5.3)$$

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[124] If technological progress is exogenous, provided that investment surpasses the depreciation, growth will occur indefinitely and no convergence is expected.

[125] Since the latter avoids further complications in the analytical representation of the technology, it is more commonly found in the literature (Nelson and Winter, 1982).

[126] For which the literature can only reduce to big categories such as innovation, imitation, product, process, incremental, radical, disembodied, embodied, etc.

[127] Innovation is ultimately a stochastic process in the sense that both the discovery and choice for the successful technique has a large component of randomness. Market factors, historical and institutional conditions, and/or a mere act of circumstance can impart on the success or failure of a new marketed innovation. This is obviously reflected in the costs of innovation and in profitability rates.

In (5.3) a linear revenue function determined by a constant technique (A_j) is assumed. $c = (wL_i + rK_i)$ represents the total costs, and r_j the cost/return of the innovative activity j. Since the market is competitive, the actions of individual firms have a negligible impact on prices, which are determined at the sectoral level, by a downward-sloping demand function[128].

If one assumes that the market for innovations follows the Schumpeterian type of competition[129], then successful firms will reap the benefits of their discoveries, while competitors may lose their investment. Hence, it is straightforward that successful businesses will grow in comparison to less-successful ones, both by expanding their market share (as the result of gains in either price or quality competitiveness), and for being in a better financial position compared to less successful firms, which will likely result in new investment by the firm.

The connection between investment, profitability, technology and firm size is then complete. A profitable firm tends to invest in its expansion and in the improvement of the technique it uses. The mechanism that governs growth is the process of investment, which is related with the firm's profitability, a hypothesis with many antecedents in the literature[130]. Retrieving the AK model solution, one can now redefine the growth of productivity as[131]:

$$\dot{q}_{it} = \dot{k}_{it} = \lambda_{it}\pi_{it} \qquad (5.4)$$

---

[128] Since the good produced in the sector is considered homogenous, its price is determined at the sector level, having the firm a negligible impact over it. Likewise, capital and labour costs both (interest rates and wages, respectively), can also be considered fixed for the same reasons (are assumed homogeneous and determined at the sector level):

$$P_t = D(Q_t), W_t = W(L_t), R_t = R(K_t)$$

[129] *"Schumpeterian competition is, like most processes we call competitive, a process that tends to produce winners and losers. Some firms track emerging technological opportunities with greater success than other firms; the former tend to prosper and grow, the latter to suffer losses and decline. Growth confers advantages that make further success more likely, while decline breeds technological obsolescence and further decline"* (Nelson and Winter, 1982 p.325).

[130] This is especially important for a firm that does not employ their own personnel on R&D activities. Investment becomes less dependent of the profitability when an in-house structure of R&D is functioning.

[131] The existence of financial institutions lending capital changes this picture. Especially if one considers that credit is not equally available to smaller firms as it is to larger ones. On average, though, assuming that investment responds to the profitability conditions is not far-fetched. Investment (or process of search and selection) is far more likely to be pursued by profitable firms. Financial institutions also require health certificates from firms applying for money and are likely to grant credit only to profitable ones.

where $0 < \lambda < 1$ is the factor of proportionality between investment and profitability, working as a discount factor, or the profit-elasticity of the investment, which depends on the firm's perception of the investment's return. It follows that any positive investment only occurs if $\overline{W_t}L_{it} < \overline{P}_t A_{it}$. In such conditions, the firm's expansion depends on the rate of success of the technique adopted, i.e., how the technical quotient (A_{it}/L_{it}) evolves. Note, however, that changes in the relative prices (P_t/w_t), which are determined in the sectoral level, also impart on the firm's choice to expand[132].

Ultimately, the parameter λ represents the intra-sectoral range of technologies, since A_j is given. As the intra-sectoral depiction of technology, λ is expected to display not a linear, but a logistic relationship between investment and profitability, both for the investment increases with the growth of the firm's capacity, as well as for it slows down as the firm reaches a certain level of market power, despite the profitability level.

Indeed, several aspects prevent the system from an explosive trajectory: (i) despite its cumulative nature, innovation success is ultimately stochastic at the firm level, making the winners and losers, up to a point, unpredictable; (ii) technological spillovers may also contribute to increasing the productivity of the surrounding - less innovative - firms; (iii) a number of firms may choose to compete by imitating the technological leader, reducing the market share of the latter; (iv) successful firms tend to follow their basic routines and not necessarily increase search activities (also known as 'investment restraint')[133]; (v) because of demand conditions and scale economies, large scale enterprises do not produce for the smaller market niches, even though these tend to become especially relevant at higher levels of income and development[134]; and (vi) the effect of anti-trust regulations, etc.

The scale of production itself might impact negatively the level of innovation due to: (vii) the absence of active competition in concentrated markets, which reduces the investment in search activities; (viii) the rise of opportunity costs to innovating, since this activity displaces part of the monopolistic returns for dominant firms, and also reduces the profit outlook for smaller firms; (ix)

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[132] For example, changes in the number of firms in the sector, or at the level of concentration, and even the exit of a big player can modify those relative prices and change the firm's behaviour.
[133] This is illustrated in the concept of 'satisfycing', originally proposed by Nelson and Winter (1982).
[134] Development is associated to market diversification also on the demand side – diversification of tastes.

bureaucratic inertia and loss of managerial control, usually associated with the large scale of production (Cohen, 1995).

Equation (5.5) below goes beyond Nelson and Winter's (1982) original model to proposes a simple rule for λ derived from the mark-up pricing-rule. Along with a multitude of factors such as level of competition, size of the market, firm strategy, local regulation and institutions, etc., the incentive to turn profits into investment should depend on the expected revenue. This will vary with both (i) the nature of the technique applied, which is responsible for the shape of the function; and (ii) the scale of production (firm size), which gives the actual point where the firm finds itself at the technological progress function, i.e., the technological gap.

A conservative hypothesis is thus that whenever the input-output ratio is decreasing, the firm continues to turn profits into investment. Profits are diverted to other ends when this ratio is either stagnant or increasing. For any individual firm, an increase in the input-output ratio is a sign that the technological boundaries have been reached[135]. An increase in output will possibly hurt the firm's profitability, either because the excess of supply should reduce the revenue price, and/or for the scale of production may cause input prices to rise[136]. In other words, the ratio shows the limits the technology and, arguably, only firms competing for market leadership will invest beyond this point.

$$\lambda \sim \begin{Bmatrix} 1, & if\ \frac{\partial^2 q}{\partial k^2} > 0\ and\ \frac{\partial q}{\partial k} > 0 \\ \sigma > \lambda\ < 1, & if\ \frac{\partial^2 q}{\partial k^2} \leq 0\ and\ \frac{\partial q}{\partial k} > 0 \\ 0, & \frac{\partial q}{\partial k} \leq 0 \end{Bmatrix} \qquad (5.5)$$

Where σ is the depreciation rate. According to (5.5), if the marginal return from investment expenditures is positive ($\frac{\partial q}{\partial k} > 0$), there are incentives to spend the excess returns in the expansion of the output. This is especially relevant if the actual level of production is in the 'band of technology' for which the rate of return of the investment increases with additional investment ($\frac{\partial^2 Q}{\partial k^2} > 0$). λ establishes a straight connection between profits and investment in the firm's expansion of business in this band of production. From the inflexion point ($\frac{\partial^2 q}{\partial k^2} = 0$) onwards, each

135 This hypothesis also makes more sense than proposing the adjustment by considering either labour or capital costs, since these are of much more complicated perception by agents.
136 E.g., the firm has reached the point in which it has a considerable monopoly or monopsony power.

additional unit of investment returns a positive, but smaller rate of revenue. At this band of production, λ depends on the competitive strategy adopted[137]. Leading innovators will probably continue investing most of their excess returns, while others might choose to lower the investment until the point it simply offsets the level of depreciation (σ), in order only to keep the actual stock of capital. This is the case for all firms when the total return of the investment is close to zero[138]. Investment is finally cut off (resulting negative) when the return of the expenditure is negative. The key hypothesis is then that the firm size is the element determining how profitability and investment affects the firm's expansion, by affecting the point the firm finds itself in the exogenous (sector-determined) technological progress function.

5.2.2. The sectoral implications: beyond microfoundations

With A_j determined by the knowledge base governing the sector, the sectoral productivity will depend on the distribution of capital amongst the firms populating the sector, that is, the distribution of firm-sizes. This important result follows from the technical condition that makes, for each sector, large firms more productive in every unit of labour employed. Accordingly, since the technology is labour-saving in most of its producible branch, the sectoral output will be as high as the level of concentration of the market-structure. Nelson and Winter (1982) illustrate this condition with a traditional Herfindhal-Hirshman index, although any concentration index would suffice:

$$q_t = \sum_{i=1}^{n}\left(A_j \cdot k_{it}\right) = \sum_{i=1}^{n}\left(\frac{k_i}{k}\right)^2 s.t\ \bar{A} \qquad (5.6)$$

Three important results derive from the above. Firstly, within a technological regime, the investment rate, level of output, and ultimately the growth rate are determined by the sectoral level of market concentration. Secondly, from the sectoral perspective, economic development can be expressed as a simple selection process, as in the linear model (Scherer, 1965) and the seminal Evolutionary models (c.f. Nelson and Winter, 1982). Finally, given the logistic shape of the sectoral function of technological progress (A_j), mid-concentrated sectors will grow faster than sectors that are highly or lowly concentrated.

[137] Such perception depends on how the firm sees the odds of success in innovating.
[138] At this point, there are no more scale economies to take advantage of.

If increasing the concentration of firms is a shortcut to growth, one has yet to assess if sectors will concentrate throughout the development traverse. According to Schumpeter (1942) the answer is yes, for the type of competition in innovation markets produce winners and losers. That is, "*some firms track emerging technological opportunities with greater success than other firms; the former tend to prosper and grow, the latter to suffer losses and decline. Growth confers advantages that make further success more likely, while decline breeds technological obsolescence and further decline*" (Nelson and Winter, 1982 p.325). More importantly though, "*as these processes operate over time, there is a tendency for concentration to develop even in an industry initially composed of many equal-sized firms*" (Ibid, p.325). Simulation exercises produced by the authors showed that despite the number of firms included, the Schumpeterian competition will lead to the consolidation of the sector. The higher the number of firms included in the initial simulations, the higher the level of concentration of the output in equilibrium. Conversely, the smaller the number of firms, the more stable will be the evolution of market shares. "*Our experimental results indicate that the tendency to increasing concentration, arising from the workings of the competitive process itself, is quite strong – strong enough to be interesting from a policy point of view*" (Ibid, p.325).

5.2.3. Illustrating the sectoral traverse

The most interesting aspect of the model above is what it has to say about the new traverse and the characteristics of the industry along the path. To simplify the analysis, consider an economy with only one sector, but two types of technology: the first adopted by low scale enterprises and the second, more efficient, adopted by large scale ones. Let thus A_s represent the productivity of the technology employed in small enterprises, and $A_l = \alpha A_s$ $(\alpha > 1)$ the technology in large enterprises. At any time, the output per unit of input will be the weighted average of employment by each sector, the weights being the output share of each technology:

$$q = A_s k_s + \alpha A_s k_l = (k_s + \alpha k_l) A_s \qquad (5.7)$$

Where k_x represents the fraction of the input for each of the technologies. Since prices are exogenous and $\dot{q}_i = \dot{k}_i = \lambda \pi_i = \lambda(P - rA_i)$, the path of equilibrium for this economy is given by the rate of take-over of the small by the large firm technology:

$$\frac{d}{dt} log\left(\frac{k_l}{k_s}\right) = \dot{k}_l - k_s = \lambda r(A_l - A_s) = \lambda r(1 - \alpha)A_s \qquad (5.8)$$

Where r, as before, represents the costs of inputs (wages and services of capital).

Hence, the rate of growth of k_l/k_s (and q_l/q_s) will be greater the bigger is λ, the growth of input costs r, and the relative productivity of the large scale technology in comparison to the small scale one. Over the traverse, k_l/k_s and q_l/q_s will trace a logistic trajectory, being slow at the beginning, followed by an acceleration and then slowing again when the higher equilibrium is approached[139]. The optimal level of concentration in a sector will depend on the characteristics of the competition and other institutional and political elements that affect the behaviour of the firms within it. As a rule, though, one can say that the more concentrated the firm distribution, the higher the sectoral level of productivity. Chapter 6 will discuss the role of the technological regime in the determination of the potential shape of the sectoral market-structure.

5.3. Empirical investigation

Although cumulative, firm-level innovation is a complex, variegated and ultimately stochastic phenomenon. Such a realisation is in the origins of the Evolutionary criticism of the neoclassical theory (especially of steady state conditions). Indeed, with growth endogenous and both the set of innovation choices and their odds of success unknown, the usual maximisation exercises and even an analytical response for the problem are but far-fetched (Nelson and Winter, 1982).

Nevertheless, approximating the theory to the actual behaviour of agents has its drawbacks. Since the distribution of probabilities of success and return rates of different innovation efforts are hardly known, testing the implications of Evolutionary models have always been a complicated task. Simulation and, more recently, agent based models became an epithet and only solution to test the empirical implications of the Evolutionary literature. The problem with such strategies is that their outcome depends on the discretionary choice of values for parameters and modelling conditions[140]. Nelson and Winter (1982, p.326) acknowledge this shortcoming: "*we think of our results [...] might ultimately provide a basis for empirical test of some descendant of the present model, but there is obviously much work to be done before such testing would be feasible or appropriate*".

[139] Nelson and Winter (1982, chap. 10) give more detail on the hypotheses and also present the analytical result for the case with several technologies and inputs. The overall conclusions are though unchanged.

[140] Although versatile in their use, simulation and agent-based models might involve the discretionary choice of the structure of the model and calibration of parameters, becoming subject to a vast range of criticism, for the more conservative one is in this process.

The model presented in the last section overcomes this limitation of the Evolutionary growth framework. By switching the perspective from individual firms to their collective, it eliminates the stochastic component from the analysis. This contributes to enable the empirical test of hypotheses at the same time that it increases the model's manageability, without loss of meaning for basic units (firms)[141]. The adoption of meso- instead of micro-foundations is a growing tendency in the Evolutionary theory (Dopfer, Foster and Potts, 2004). The basic premise is that an intra-sectoral perspective – rather than the individual firm analysis – reveals collective patterns that simplify the stochastic behaviour of micro agents, giving thus important foundations to macro modelling.

As a first approximation for the problem, section 5.3.1 presents a number of summary statistics for the collective of firms in the intra-sectoral database[142]. The unit of analysis is the firm size class in the world economy (resulting from the aggregation of the data for the 35 countries in the sample). Section 5.3.2 tests some important hypotheses of the model at a country level. As the results reveal, part of the intra-sectoral development process still needs further qualification, especially in what concerns the role of demand in the growth process. This is addressed in Chapter 6.

5.3.1. Preliminary exploratory analysis

Table 5.1 below presents the output and employment shares and their growth rates for each size class in the intra-sectoral database. Small companies (NSC-1) account for less than 5% of the total output in industry, but employ almost 11% of the labour force. At the other extreme, large firms (NSC-5), produce 57.6% of the output employing less than 40% of the total labour force. Across all size groups, the evidence indicates that the level of technology in manufacturing – proxied by the technical share $((Q_i/Q_{Tot})/(E_i/E_{Tot}))$[143] – increases monotonically with size. This seems to confirm Geroski and Machin's (1992) finding that persistent asymmetries in technological competencies are accumulated through the process of innovation and growth.

[141] Such an approach has also the advantage of making a counterpoint to sectoral simulations found in Nelson and Winter (1982).

[142] Appendix 2 presents the units, sample selection and variables.

[143] The technical share is different from labour productivity for it is the quotient of the two shares in total output and employment, respectively. That is, it represents the ratio of the sector's productivity to the average.

Table 5.1 - Technical shares and growth rates by size class: world economy, two-period average (1990-1999/2000-2007)

National Size class	Employment		Output		Technical ratio[2]	
	L[1]	Δ	Q[1]	Δ	rate	Δ
NSC-1	0.108	42%	0.048	49%	0.448	117%
NSC-2	0.091	19%	0.049	27%	0.536	139%
NSC-3	0.146	17%	0.098	24%	0.670	140%
NSC-4	0.257	23%	0.229	30%	0.892	130%
NSC-5	0.398	19%	0.576	22%	1.446	120%
Average	**0.200**	**24%**	**0.200**	**30%**	**0.799**	**129%**

Notes: [1] Shares. [2] Ratio of output and labour employment shares.
Source: author's own elaboration (data from the SDBS)

A basic assumption of the model is that successful firms accumulate capital and grow as result of it. Therefore, one can picture each size class as a snapshot of an individual firm at a different stage of the development trajectory, where the productivity index reveals the level of technology associated with it. The growth rates (Δ), calculated as the difference between the averages of the two decades (1990-1999 and 2000-2007), illustrate the dynamics of the process of technical change. Across the five size classes, the growth of the technical ratio describes an (almost perfect) inverted U trajectory. That is, if one assume that the technical ratio represents the level of technology at use in the firm, innovation accelerates with capital accumulation (increases in size) peaking at a medium-sized businesses (NSC-3), from which point it slows down to equal at large enterprises (NSC-5) the level of innovation found for small ones (NSC-1). This description is compatible with the traditional quadratic cost function, where fixed costs, indivisibility conditions, etc., overburden lower scales of production, but is diluted in higher scales. Such increasing returns to scale will though revert when either (i) the technical capacity is reached, or (ii) the excess demand raises input prices.

Table 5.2 - Cost structure by size class: world economy average (1990-2007)

National Size class	Costs				
	Investment	Surplus	Wages	Intermediate Inputs	Gross cost*
NSC-1	0.032	0.116	0.118	0.555	0.789
NSC-2	0.021	0.067	0.140	0.481	0.688
NSC-3	0.025	0.054	0.140	0.480	0.674
NSC-4	0.030	0.060	0.137	0.469	0.666
NSC-5	0.031	0.064	0.112	0.509	0.685
Average	**0.028**	**0.072**	**0.129**	**0.499**	**0.628**

Notes: All measured as proportions of the size class total revenue. * Before investment and excluding the cost of capital.
Source: author's own calculation (data from the SDBS)

The cross-size quadratic shape of the cost function is clear from the Table 5.2, although this does not follow from the costs of labour, since wages describe the opposite trajectory, but from the costs of 'intermediate inputs'. The gross costs measure (wages + inputs) decreases across size classes reaching a minimum value for NSC-4 firms. The same pattern is found when adding surplus and investment to the gross cost measure. The increase in costs for NSC-5 firms corroborates the hypothesis that the rather large size of the firms in this category is likely to pressure the firm's costs, especially the costs of intermediate inputs, since wages are decreasing.

More importantly, the loss of dynamicity in the extremes (small and large firms) is perfectly compatible with the hypothesis a S-shaped function of technological progress: the inclination of the curve is higher for medium-sized businesses and flatter for small and large business, where the likelihood of technological progress is lower.

Table 5.3 compares investment ratios, surplus and the labour productivity, estimated as in the last chapter (gross output/employment). The productivity index increases monotonically with size, indicating the close relationship between size and technology level. The table also informs about another crucial hypothesis of the model developed in the last section: the close relationship between the level of investment, technical change (productivity growth) and profitability. The values for the rate of growth of the productivity and the investment rate (as a share of the output) match each other in each size class, except in the group of large business, for which the first exceeds the latter. This is a clear indicative of the cumulativeness of the innovation process, and of the special importance of large firms for sectoral growth.

The R&D spending as a proportion of the total investment also shows a disproportional level of R&D expenditures by large companies (NSC-4 and, especially, NSC-5). For comparison, R&D accounts for an average of 40% of the total investment in large firms, but only 5% in medium firms. This difference indicate that either smaller business pursue alternative innovation strategies and/or large-firms expenditures are less focused on the pure expansion of business, but in the development of new production techniques, i.e., pushing out the technological frontier, as many studies suggest that R&D expenditures are essential for radical innovation (Freeman and Soete, 1997). As seen in Table 5.2, the rise of input costs affects specifically large companies. This may contribute to reduce their drive to expand production. It follows from the above that large firms should lead the process of technological progress in a sector, and this might be reason for which large business perform better in a multiplicity of measures such as profitability, growth rates and market shares (Geroski and Machin, 1992; Baldwin and Johnson, 1995).

Table 5.3 - Investment ratios, surplus and productivity by size class: world economy, average (1990-2007)

National Size class	Productivity		Investment			Surplus*	λ***
	Index	Growth rate	Total*	R&D**	R&D personnel**		
NSC-1	0.095	0.032	0.032	0.095	0.002	11.60%	0.275
NSC-2	0.115	0.021	0.021	0.077	0.001	6.74%	0.312
NSC-3	0.145	0.026	0.025	0.054	0.002	5.48%	0.456
NSC-4	0.192	0.031	0.030	0.085	0.006	6.04%	0.497
NSC-5	0.312	0.036	0.031	0.387	0.022	6.36%	0.487
Average	**0.172**	**0.029**	**0.028**	**0.140**	**0.007**	**7.24%**	**0.405**

Notes: *Proportion of total revenue. **Proportion of total investment. *** Investment share/surplus share.
Source: author's own calculation (data from the SBDS)

Lastly, Table 5.3 also reports a measure of λ, the factor of proportionality between investment and profitability (See Equations (5.3) and (5.4)). The measure is presented as a simple quotient of the investment and surplus proportions of the total revenue. As seen, it seems to describe a quadratic path across size classes, even though λ value is close for NSC-4 and NSC-5 firms (which would confirm the logistic path expected). This divergence from the expected logistic trajectory will be further discussed in the next section.

Overall, even though no distinction between sectors is made, the data seems to confirm and reinforce all the premises of the model presented in section 5.2[144], with a qualification yet to explore regarding λ trajectory. As it will be explored in the next Chapter, the disaggregation of the data in sectors/technological regimes only improves the conclusion that size is a central variable for understanding the process of economic development.

5.3.2. Assessing the basic hypothesis of the model

The exploratory analysis in the previous section seems to confirm the cycle that connects innovation, profitability, investment and growth. Since technological progress is a cumulative process, which results in capital deepening as the firm grows, the firm size possibly influences the subsequent

[144] There is a multiplicity of patterns associated to specific sectors, even though the general conclusions are not changed for country subsets of the data.

innovation. This is not a monotonic process, as firms will face decreasing incentives to turn their profits into further expansion as they grow larger. If not, the concentration of the market-structure would persist until one firm dominates the entire market. From the above, at least two key hypotheses deserve a more thoroughly investigation: (i) the positive relationship between firm size and technology level; and (ii) the non-linear relationship between investment and profitability and how it is influenced by size.

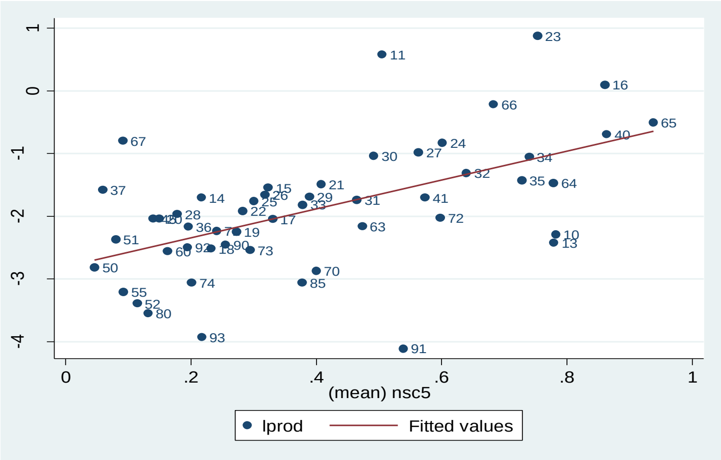
5.3.2.1. Size and Technology level

There are two simple ways to assess the relationship between firm size and level of technology. The first is to investigate the impact of size on innovation. This discussion, however, has been historically constrained by the controversy around the measurement of innovation. The main input and output of the process, R&D expenditure and patents, respectively, are controversial units of analysis, as more patents and bigger R&D expenditures do not necessarily translate into better innovation results (Freeman and Soete, 1997). Moreover, R&D is just one of many innovation inputs and, allegedly, mostly adopted by large businesses (Cohen, 1995). Alternative units are abundant in the literature (see Chapter 1), but each can only depict a specific dimension of the innovation process, failing to represent the firm's global innovation effort and outcome (c.f. Evangelista and Mastrostefano, 2006; Cáceres, Guzmán and Rekowski, 2011).

A less controversial strategy – in a supply-oriented approach – is to assess the relationship between firm size and the productivity index[145]. The evidence summarised in section 5.3.1 showed that large firms do indeed present higher levels of productivity, indicating that firm size [or the concentration of the market-structure] may be the visible facet of the technology at use. As the figures did not differentiate between sectors, Figure 5.1 depicts the sectoral participation of large firms in total employment (a proxy for concentration of the market-structure) by the level of productivity. The fitted values confirm a positive correlation between sectoral concentration and productivity.

[145] The literature on the endogeneity of the natural growth rate re-qualifies this assertion (see Chapter 8).

Figure 5.1 - Sectoral concentration and labour productivity by ISIC2 sectors



Notes: Vertical axis: lprod = log-level of labour productivity; Horizontal axis: NSC-5 firms share in total employment. Fitted values significant at 1%.
Source: author's own calculation (data from the SDBS)

Next chapter proposes a seminal exercise to assess the size class differences in the dynamics of the process of technical change. The analysis is based on the Kaldorian growth model and the breakthrough results indicate that the technology is labour saving: the bigger the firm, the less it depends on labour employment to increase production. More importantly, the level of returns to scale increases with size, confirming the hypothesis that firms incorporate technological progress in the development process, altering their technology as they grow bigger.

5.3.2.2. Profitability, investment and size

Equation (5.4) proposed that profitability and investment are intimately connected ($\dot{k}_{it} = \lambda_{it}\pi_{it}$)[146]. One key hypothesis in this chapter is that firm size mediates the relationship between profitability and investment so that understanding the shape of λ_{it}, the coefficient of proportionality between the two, is central. Consider thus the following econometric model derived from (5.4):

$$\log{(\dot{k})_{it}} = \propto_1 \log{(\pi_{it})} + \propto_2 \lambda_{it} + \beta \log{(X_{i,t})} + \mu_{i,t} \tag{5.10}$$

Where $\dot{k}_{it}$ is the total investment in country i and year t, π_{it} profits, $X_{i,t}$ is a vector of control variables and $\mu_{i,t}$ the error term. Both investment and profits (gross surplus) are from the SDBS. The control group includes de the income per capita (Y) and human capital from the Penn World Table 9.0, and country and year dummies.

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[146] The reverse relationship is also expected as higher investment increases the technology and thus profits.

Table 5.4 - Investment function: cross-country (1990-2007)

Variable	Fixed-effects	Fixed effects	FE IV regression	FE IV regression
Log (investment)	(i)	(ii)	(iii)	(iv)
λ	7.3285***	16.0678***	19.4191***	16.1757***
Log(π)	0.2697***	0.2648***	0.2614***	
λ^2	-89.4137*	-97.4220**	-90.3665*	
Log(Y)	0.0578			
Constant	4.2493***	4.1727***	5.8664***	3.4604
N	1456	1456	2059	1456
R^2	0.1686	0.1676	0.0476	0.2254
rmse	0.3091	0.308	0.366	0.308
corr	0.0105	-0.0014	0.0635	0.0653
F	23.526	16.7421	20.1143	13.6869

Notes: λ = share of employment of NSC-5 firms. π = surplus. Y = income per capita.
*** significant at 0.1% ** significant at 1% * significant at 5% .
Estimated in the panel across countries and time by robust variance methods.
The results are similar when estimated using only an average of the years in the sample. Year dummies were not significant. NSC5 was instrumented by Y and π in column (iv).
Source: author's own elaboration (data from the SDBS)

Table 5.4 summarises the results of the regression of equation (5.10) for the 35 countries in the database using robust panel data methods with fixed-effects. Different methods and aggregations of the data are presented, where all show the same pattern[147]. λ_{it} is proxied by the share of NSC-5 in total employment. The coefficient is positive and significant at 1% level in all specifications. More importantly, the relationship between concentration of the market-structure and investment is not linear, as the significance of the quadratic term (λ^2) shows. The fact that λ^2 is negative indicates that the concavity of the curve is negative, suggesting a quadratic relationship. Profits, as expected, present a positive and significant relationship with investment. The logarithm of per capita income and human capital were excluded from estimations (ii) to (iv) due to their non-significance.

In a different exercise, equation (5.10) was estimated for each size class[148]. The estimates in Table 5.5 show a clear decreasing pattern in the relationship between profits and investment across size classes. Since the model was estimated in log-levels, the parameters should be interpreted as elasticities. Hence, an increase of 1% in profits will result in an increment of 0.75% in the investment

[147] See Appendix 3 for a discussion on panel data methods.
[148] Note that λ is omitted from the specification since the I-P relationship is estimated for each size class.

for NSC-1 firms, whereas for NSC-5 firms the investment will increase by only 0.41%. The differences across size classes are not affected by the inclusion of controls[149].

Table 5.5 - Investment function by Firm Size class: cross-country (1990-2007)

Variable Log(Investment)	NSC-1	NSC-2	NSC-3	NSC-4	NSC-5
Log(π)	0.7477***	0.5301***	0.4475***	0.4441***	0.4142*
Constant	0.9758	2.4194***	3.1768***	3.7437***	4.3585**
N	137	137	139	136	130
R^2	0.4008	0.3267	0.3487	0.3187	0.3805
rmse	0.4586	0.5114	0.4692	0.4782	0.5546
corr	-0.3224	0.0289	0.179	0.1348	0.3084
F	36.3177	47.6938	24.5655	27.0448	6.302

Notes: Estimated in the panel across countries and time by robust variance methods. The endogenous variable is the output. The results are similar when estimated using only an average of the years in the sample. Controls ommited.
*** significant at 0.1% ** significant at 1% * significant at 5%.
Source: author's own elaboration (data from the SDBS)

The results above confirm the hypothesis that firm size seems to influence the relationship between profits and investment. As firms grow, they face less incentive for turning profits into further growth, suggesting fewer technological opportunities for these large firms, which are close to the technological frontier. Against the initial expectations, however, the decreasing cross-size estimates of λ and the significant λ^2 indicates the influence of an unexpected factor in the choices of large business, resulting in a quadratic and not logistic λ. Finally, the results in this chapter should be interpreted with caution as no distinction is made between sectors. This is explored in the next chapter.

5.4. Concluding remarks

Following Nelson and Winter's (1982) growth model, this chapter showed that, since technological progress requires some level of capital deepening as the firm grows, the firm size is a key element in the growth trajectory. This was shown to be a non-monotonic process though, with firms facing decreasing incentives to turn profits into a further expansion of capacity as they grow. The empirical evidence confirmed both a positive relationship between size and technology level, and a non-linear relationship between size, investment and profitability, corroborating some of the hypotheses of the model introduced in the second section.

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[149] The high correlation between residuals and estimators for NSC-1 and NSC-5 firms suggest though that the specifications for these classes might be omitting important variables, even though the F test attest the validity of the model and the R^2 indicates a good adjustment.

As the next chapter will explore, the unexpected behaviour of large firms is influenced by elements at the demand side. The results confirm the logistic assumption for the natural trajectory, yet demand constraints affecting large businesses specifically end up shaping the actual market-structure composition. As income and demand grows, smaller firms regain part of the market share lost in the process of development, probably because they attend specific niches opened by the process of economic development, thus reducing the level of sectoral concentration. This explains the highlighted importance of medium-sized firms for growth in misallocation studies (c.f. Hsieh and Klenow, 2009; Jones, 2011). Developed countries should indeed display an intermediate level of sectoral concentration. The causes of this phenomenon are further discussed in the next chapter.

Finally, it is worth mentioning that the framework above not only explains the evidence on the misallocation literature, as it provides much needed foundations for this phenomenon. Yet, the ideas and evidence above still need to be reconciled with the notion of technological regimes. As discussed in the first chapter, the Evolutionary literature provided considerable evidence on the role of the sectoral knowledge base in the determination of technological regimes. Indeed, the next chapter shows that 62% of the productivity index's variance is explained by the sector[150], reinforcing the relevance of a multi-sectoral assessment.

[150] The ANOVA investigation showed that 18% is explained by the country variability and that the interaction sector x country accounts for the remaining 21%.

6 Market concentration and technological regimes: exploring the role of supply and demand in sectoral growth trajectories

6.1. Introduction

Last chapter explored the micro-foundations of the process of intra-sectoral development. Building upon Evolutionary ideas, the approach brought the firm size (concentration of the market-structure) to the centre of the process of sectoral development. Data on investment, profitability and productivity its components corroborated a non-linear relationship between firm size, innovation and growth. Yet, the analysis treated technological progress as an undifferentiated process, whereas the current stand in the Evolutionary literature defends the endogeneity of both market-structure and innovation in the sectoral technological regime (Marsili, 2001).

This chapter discusses further the role of firm size in development trajectories. It proposes a general, but flexible function of technological progress, which can be calibrated to reflect sector-specific characteristics, such as the levels of appropriateness, cumulativeness and technological opportunities determined by the knowledge-base (Malerba and Orsenigo, 1990). Accordingly, the concept of 'technological regimes' gives the path of development, whereas the actual trajectory is determined by the level of concentration of the market-structure. The approach has the advantage of preserving the central role played by firm size in such trajectories at the same time it emphasises the well documented sectoral differences in the innovation process[151].

Nevertheless, as in the last chapter, the evidence shows a divergence between the predicted logistic path and the actual quadratic (inverted U) relationship between concentration of the market-structure and sectoral development. This indicates that the development traverse involves the concentration market-structure at early stages and de-concentration in mature stages. The supply dynamics, incorporated in the trajectory of technological development can only explain the first part of the traverse. The ensuing discussion proposes an unaccounted influence of demand influencing

[151] See Chapter 1 for a review.

the final trajectory, changing the expected traverse. This is further explored in Chapter 9, which focuses on the interplay between the technological progress function and demand factors[152].

Given the obvious importance of both demand and supply in such trajectories, the second part of the chapter investigates the level of constraints imposed by each in the traverse. This is done by the estimation of the Verdoorn coefficient[153] and income elasticities for each size classes[154]. This seminal approach aims at both investigating whether the logistic technological progress function is empirically supported, and assess the role of demand, represented by the income elasticity, in the actual trajectories.

The investigation leads to two important conclusions: (i) the level of returns to scale increases logistically with firm size, as proposed by the model; (ii) the income elasticities, however, is considerably lower for large firms, indicating a central role of demand in the noted divergence in trajectories. In summary, the approach reveals that the intra-sectoral 'natural trajectories' are supply-led. Nevertheless, the influence of the demand is key for the final shape of the market-structure and the equilibrium growth rate. This explains much of the controversy around the empirical validity of Schumpeterian hypothesis in the literature. The inverted U path makes it necessary to estimate the impact of firm size on innovation locally or by non-linear methods, since the role of firm size in the growth process vary in the traverse. Such an approach has yet another important contribution. By estimating the Kaldorian parameters at the intra-sectoral level, the approach casts light on the foundations of these important elements enabling a range of policy implications (King, 2010). These are further explored in Chapter 9 and 10.

6.2. Technological regimes and trajectories

According to Nelson and Winter (1982), firms are "*agents in possession of various capabilities, procedures, and decision rules that determine what they do given external conditions in the demand*

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[152] Chapter 9 shows that the process of development of the supply reveals itself in the intra-sectoral development trajectory, whereas the process of development of demand is visible in the inter-sectoral development trajectory. While the first imposes bottom-up changes in the system, the second imposes marginally contradictory top-down forces. It concludes that the interaction between these layers may explain both the quadratic relationship between firm size and sectoral development and divergent patterns of specialisation at the inter-sectoral level.

[153] Although much of the recent efforts in the Kaldorian literature focus on exploring the foundations of these parameters, to date, the Verdoorn law and income elasticities have never been assessed at the intra-sectoral level.

[154] As discussed in Chapter 2, these structural parameters represent both demand and supply requisites for growth in the Kaldorian framework.

and supply" (*Ibid*., p.103). In pursuit of temporary monopolies, they allocate part of their resources in 'search' activities, aimed at the discovery and evaluation of new techniques and products. The innovation process, however, vary significantly. Elements at the firm (Patel and Pavitt, 1997), sector (Malerba and Orsenigo, 1993) and even at the country-level (Lundvall, 1993; Freeman and Soete, 1997) influence the inputs and outputs of this process.
The current stand of the Evolutionary literature (Malerba and Orsenigo, 1993; Breschi and Malerba, 1997; Marsili, 2001) largely emphasises the influence of the sectoral knowledge base in the determination of the innovation strategies followed by the firms. The characteristics of the knowledge, particularly its level of cumulativeness, appropriability, opportunity and other elements such as the level of barriers to entry, define what is called by 'technological regime'. A technological regime assures some degree of uniformity of firm's views and actions towards innovation, as well as their competitive strategies (be it to lead or follow competitors, imitate or innovate, etc).

As discussed in the first chapter, the technological regime provides a synthetic representation of the economic properties of sectoral technologies and learning process. These set the boundaries of what can be achieved by problem-solving activities, shaping 'natural trajectories' along which solutions to these problems can be found (Castellacci, 2004). Ultimately, a technological regime gives a simplified yet considerably more accurate description of the nature of technological progress in comparison to the linear model, for which innovation was an undifferentiated process that emerges as a natural consequence of R&D expenditures.

Technological regimes, however, cannot explain either the large disparities between firms in the same sector or the distinct patterns across countries. In fact, industries are known to "*differ significantly in the extent to which they exploit the prevailing general natural trajectories, and these differences influence the rise and fall of different industries and technologies"* (Nelson and Winter, 1977, p.59)[155]. Hence, identifying the elements determining departures from these natural trajectories is the key to understand the evolution of a firm, sectors and countries.

As in the seminal Evolutionary studies, this chapter highlights the role played by the firm size (sectoral concentration level) on innovation trajectories. This follows from a basic condition of competitive markets: given the close connection between investment and profitability, firms whose

[155] This is the concept of “technological trajectory”, as opposed to that of “technological paradigm” (Dosi, 1984).

decision rules are profitable expand (generally at the expense of those that are unprofitable, which might shrink). Accordingly, demand conditions and supra-normal profits lead to market dominance with the consequent gain of market share by these firms. Likewise, effective imitators also thrive and grow at higher rates. Since growth is directly associated with market success, by hypothesis, the size reflects the level of capabilities accumulated throughout the firm's development and larger firms should display higher levels of productivity. This is in accordance with Malerba and Orsenigo (2000) and Cefis and Orsenigo (2001), for which firms improve their absorptive capacities, knowledge competencies and organizational capabilities cumulatively over time.

The role of firm size in the innovation process should be more central than the one reserved in the current Evolutionary literature. If the levels of technological opportunities and degree of knowledge cumulativeness and appropriability differ across industries, the weight of the influence of firm size in the innovation process should also vary. The role of the firm size in the process, however, remains key. As an element associated with the level of capabilities accumulated and being the latter the main factor of innovation success, size is both an indicator of previous success in innovation as well as a determinant of future innovation.

Indeed, the historical evidence shows that large firms have higher rates of productivity and R&D investment compared to smaller firms (Cohen, 1995). Size is also the prime factor explaining the decision whether to innovate or not (Geroski and Machin, 1992). Hence, even though determined by technological regime, the firm size should still be seen as a determinant of innovation, as established by the 'Schumpeterian hypothesis'.

One simple way to test the importance of size in comparison to sectoral and country-level elements, is by analysis of variance (ANOVA). ANOVA attributes the observed variance of a variable to a number of sources represented by the variance of the explanatory variables. It is conceptually similar to a t-test and analyses if the statistical means of different groups are equal. Table 6.1 depicts the estimated results for the ANOVA considering three sources of variation for the productivity index: the firm size class, sector, and country. The results confirm the importance of the interaction between size and other sectoral and country level elements, in spite of only sectoral elements in the determination of the sectoral productivity level.

Country (ctry), sector (ind) and size class (scl) variability account each only for a marginal part of the variance of the firm-level productivity index (1.21%, 1.35% and 0.45%, respectively). However, the interaction between these elements account for around one third of the variance of the productivity index, suggesting that the productivity heterogeneity found in the data is not explained solely by a factor in one analytical level (such as the sectoral technological regime), but by their collective.

Table 6.1 - Productivity ANOVA

Source	Partial	SS	df	MS	F	Prob>F
Country (ctry)	1.21%	34161.148	34	1004.7397	15.06	0
Sector (ind)	1.35%	37999.709	11	3454.519	51.78	0
Size class (scl)	0.45%	12682.126	4	3170.5315	47.52	0
ctry#ind	6.53%	184318.84	106	1738.857	26.06	0
ctry#scl	4.29%	121215.39	135	897.89179	13.46	0
ind#scl	4.11%	115970.86	44	2635.7013	39.51	0
ctry#ind#scl	22.57%	637404.37	341	1869.221	28.02	0
Model (R-squared)	0.339*	959090.55	675	1420.8749	21.3	0
Residual	0.660	1864812.2	27952	66.714803	-	-

Notes: The hash sign indicates an interaction of elements (multiplicative). Total number of obs. 28,628.
Source: author's own calculation (data from the SDBS)

The question now is how firm size and technological regimes interact in the sectoral process of development.

6.2.1. A general 'regime'?

In the Schumpeterian literature, firm-level innovation is a complex and variegated process with a stochastic outcome, explaining why agent-based modelling and simulation exercises are so common in this literature. A problem with such strategies is that no analytical response can be pursued. An alternative commonly found is to reduce the complexity of the innovation process to a few binary typologies[156], namely: innovation vs. imitation (Nelson and Winter, 1982), product vs. process innovation (Simonetti *et al*., 1995; Edquist *et al*., 2001); embodied vs. disembodied innovation (Evangelista, 1999; Castellacci, 2004); 'innovation-competitiveness' vs. 'cost-competitiveness' (Bogliacino and Pianta, 2008), etc. This strategy, however simpler and handy, has the disadvantage of sacrificing important distinctions, making innovation too homogeneous across sectors.

This section proposes a more flexible and schematic representation of the technological progress. The approach simplifies the representation by proposing a unique rule, instead of a number of regimes. Key parameters determined at the sectoral level enable different setups, while the

[156] A large branch of the literature is actually devoted to characterise the relevant types (see Chapter 1).

concentration of the market-structure, which synthesises the interaction between sectoral and firm-level elements, is still the protagonist in the innovation trajectories. Such a strategy avoids the excessive complications brought by the micro-stochastic representation of innovation without eliminating the sources of variability.

According to the argument in Chapter 5, innovation is driven by the process of investment and dependent on the firm's profitability. The relationship between investment and profits, however, is not linear. Ultimately, it depends on the level of capabilities accumulated, which is reflected on the firm size. Firms in possession of only a few capabilities struggle in their process of innovation. The lack of 'resources', such as trained personnel and top edge machinery, reduces the chances of being successful in the 'innovation lottery'. In general, these firms would rather outsource their innovation, buying 'knowledge' already embodied in the equipment of more innovative suppliers. Alternatively, they may become imitators of existing processes/products, for instance, as this strategy reduces the uncertainty of the investment's outcome. As the firm accumulates new capabilities though, this choice might change. Internalising the innovation might turn into a feasible strategy because it becomes less risky (costly). Ultimately, with the shortening of the distance to the technological frontier, innovation becomes again more costly. This is because innovation in such conditions requires the expansion of the knowledge frontier, an expensive and risky process as it might involve 'plunging into unknown waters'.

This description is compatible with a logistic trajectory of the firm size in the intra-sectoral development traverse. Such S-shaped curves have long been used to explain growth in many areas, from physics to biology and linguistics. In the study of technology and innovation it has been applied since the publication of *The Laws of Imitation* by Gabriel Tarde (1890). In his scheme, the rise and spread of new ideas through imitative chains can be divided in three stages: difficult beginnings, exponential take-off, and logarithmic growth.

Assuming that the capital/labour ratio (k) is a good proxy for the firm size and captures the level of capabilities that a firm i has internalised, the only variable determining the firm's technology is k with the path of technological progress laid out by the sectoral parameters. In other words, the shape of the technological progress function is exogenous to the firm, even though the process of technical change will depend on the firm's level of capabilities determined by its size. In formal terms:

$$A(k_{it}) = \frac{\omega}{1+\emptyset e^{-\theta k_{it}}} \qquad (6.1)$$

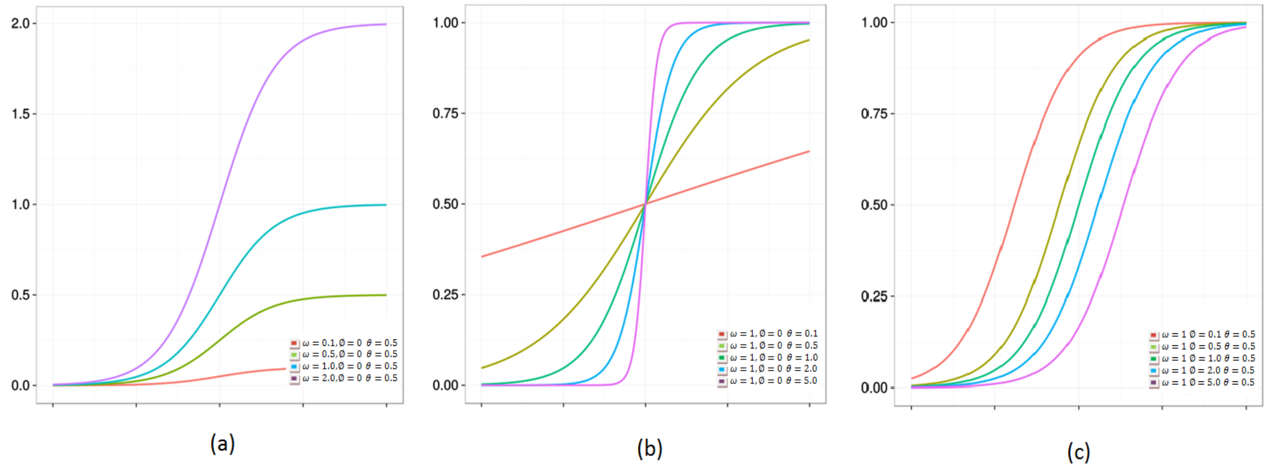
Where $A(k_{it})$ is the function of technological progress. Equation (6.1) is especially designed to reflect the costs and returns of the innovation process at different scales (levels) of production. Three parameters set the dynamics of the innovative process: ω, $\emptyset$, and θ. ω gives the upper bound (asymptote) of the process of capital accumulation, the point over which investment has no influence on the capital/labour ratio. In other terms, ω expresses the level of appropriability of the knowledge base (e.g., the potential turnover from improved products/processes). This parameter gives the maximum size (scale) a firm in the sector might achieve. $\emptyset$ is related to the value of A(0), that is, the point from which the innovative investment should start increasing the capital/labour ratio. This is the minimum level of capabilities necessary for a firm i to start developing its production, representing thus the level of cumulativeness of the knowledge base. Finally, θ gives the steepness of the curve, thus representing the technological opportunities in the sector – the easy with the investment result in the expansion of the technology and then in the accumulation of capital (not all investment is successful).

As seen, all Pavitt's (1984) parameters are represented in the above. For any firm, the level of technology (and thus productivity) is proportional to its capital-labour ratio (k). The analysis of the gradients (partial derivatives) of the function gives some clues on the evolution of the sectoral level of concentration and on the outcome of changes in the parameters of the technological regime. This is illustrated in Figure 6.1 below, which depict the potential shapes of the technological progress function as the elements above are changed. The horizontal axis represents the time trajectory of development, and the vertical axis the level of concentration of the market-structure. Figure 6.1(a) depicts four possible trajectories given changes in ω (while keeping $\emptyset$, and θ fixed). Figure 6.1(b) and (c) show changes in $\emptyset$, and θ, respectively.

Everything else equal, an increase in ω implies a higher level of technology, which makes each unit of input employed more productive. θ, by its side, will impact both the level and dynamics of the development trajectory. An increase in θ encourages higher levels of investment, which has also a positive impact on the level of productivity of the sector. However, this depends on the dynamic of the investment process and thus on the levels of profitability.

As described, the nature of the knowledge base underlying the search process in a specific sector will give the overall shape of the process of technological progress, whereas the scale of production or firm size, given by k, sets the actual position of the firm on the sectoral technology path. Accordingly, any firm in a specific sector is assumed to follow sectoral-specific technological regime.

Figure 6.1 - Potential shapes of the technological progress function



Notes: Time path in the horizontal axis and the level of concentration in the vertical axis, where 0 indicates perfect competition and 1 monopoly.
Source: author's own elaboration

Such a function of technological progress eliminates the randomness of the innovation process at the firm level and enables an analytical representation of the sectoral development process. Furthermore, the model above is compatible with both the current paradigm in the Evolutionary literature, as it highlights the role of technological regime in the determination of innovation, and the precursor studies in this school, as firm size is a key element in the process.

6.2.2. The importance of the technological regime

The empirical evidence on the relationship between firm size and innovation in Chapter 5 did not differentiate between sectors or technological regimes. One important question is hence how this relationship changes when this differentiation is made. As emphasised in Chapter 1, the literature on the topic is largely controversial. Whereas Soete (1979) and Pavitt, Robson and Townsend (1987) found empirical evidence in favour of the Schumpeterian hypothesis, after comparing different industries and controlling for industry-specific conditions, respectively, Scherer (1967) and Cohen, Levin and Mowery (1987) found that the level of R&D was not statistically influenced by firm size or level of concentration[157].

[157] See Cohen and Levin (1989) and Cohen (1995) for a review.

This section superposes the information on sectoral technological regimes with firm size trajectories. Based on the seminal classification of Pavitt (1984)[158], four sectors are defined and the average sectoral participation of large firms (NSC-5) for the countries in the intrasectoral database[159] plotted against the its structural sophistication index[160] (kc). Ultimately, this should illustrate how firm size behaves throughout the trajectory of sectoral development.

The four sectoral regimes and their basic characteristics are summarised in Table 6.2[161]. These are:

(i) Science-based: characterised by high technological opportunities (θ) and high levels of appropriability (ω) and cumulativeness (∅).

(ii) Scale intensive: characterised by high levels of appropriability/cumulativeness and low technological opportunities.

(iii) Specialised suppliers: characterised by high technological opportunities, but low levels of appropriability and cumulativeness.

(iv) Supplier dominated: characterised by low technological opportunities, and low levels of appropriability and cumulativeness.

Table 6.2 - Pavitt's (1984) technological clusters and characteristics

Knowledge base element	Specialised suppliers	Science based	Scale intensive	Supplier dominated
Level of technological opportunity	1	2	3	4
Cumulativeness and Appropriability	3	2	1	4

Notes: The numbers indicate the rank correlation between the knowledge base element and the sector, i.e., 1 for the highest value in the characteristic and 4 for the smaller. *This index
Source: author's own elaboration (Based on Castellacci (2009)).

Following this classification, one should expect higher levels of concentration of the market-structure in the scale intensive and science-based sectors. The technological opportunities indicate that firms in the specialised suppliers sector face the lowest costs in catching up with the highest

[158] As discussed in Chapter 1, Pavitt's classification has been used in a number of studies in the literature (Begg *et al*. 1999; Laursen and Meliciani 2000; Marsili and Verspagen 2002).

[159] See Appendix 2.

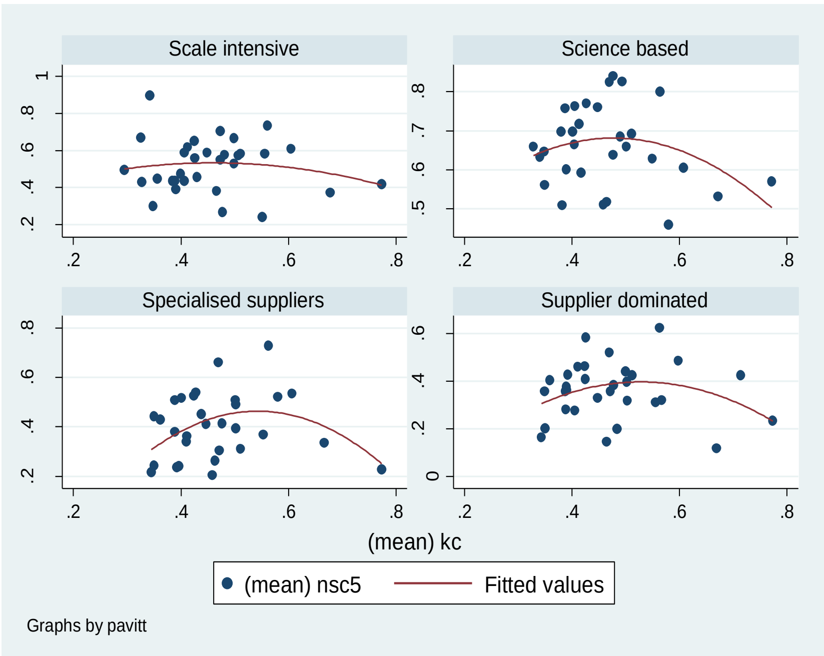
[160] The structural sophistication index was constructed following the literature on product complexity (Hausmann and Hidalgo, 2011) and is further discussed in Chapter 7. The index is higher the higher the number of products produced with revealed compared advantages (Balassa, 1965). It thus represent the level of structural complexity (or the number of capabilities internalised) by an economy.

[161] Each of the 22 ISIC-2 manufacturing industries were assigned to the categories of Pavitt's (1984) taxonomy of four regimes (See Table 1.1 in Chapter 1).

levels of productivity by investing in innovation. On the opposite end, supplier dominated should display the lowest levels of concentration and opportunities to catch up.

As a general pattern, from Figure 6.2 it is possible to conclude that the concentration of the market-structure increases in the beginning of the sectoral development trajectory, but contrary to expectations, it starts decreasing when a specific point of industrial sophistication is reached. In other words, it seems that the logistic model explains only the first half of the sectoral development process. The cause of this anomaly is discussed in the next section. At present, it suffices to note that for the first half of the trajectory, the data behaves as predicted by the model. The sectoral distinctions are also confirmed: (i) the level of concentration is especially high at scale-intensive and science-based sectors (see the levels in the vertical axis); (ii) science-based industries exhibit a much steeper curve, indicating higher technological opportunities with growth compared to scale-intensive; (iii) specialised suppliers are on average less concentrated, but exhibit the highest technological opportunities; (iv) finally, supplier-dominated firms display the lowest level of concentration.

Figure 6.2 - Market concentration and country complexity: average (2000-2005)



Notes: Share of total labour employment in NSC5 firms in the vertical axis and the average country complexity index (kc) in the horizontal axis. Database sample and preparation is introduced in Appendix 2.
Source: author's own elaboration (data from the SDBS)

The results above confirm the historical evidence on industrial dynamics and technical change showing that persistent firm- and sector-levels asymmetries can co-exist with general properties at an aggregate level (e.g., Pareto's law, Gibrat's law). This ultimately validates this thesis' pursuit of meso-foundations of the growth process.

6.3. Supply and demand requisites for the sectoral development: investigating the Kaldorian parameters at the intra-sectoral level

Last section showed that the technological regime seems to determine the potential development traverse of the market-structure (intra-sectoral trajectory), as it gives the incentives and imposes the boundaries to the firm's expansion. This section, therefore, seeks to confirm the role of the technological progress function (supply development) in such trajectories. It also investigates the hypothesis that demand constraints are responsible for the anomalous (non-logistic) behaviour of the concentration measure in the traverse.

The demand and supply requirements for growth are presented as in the canonical Kaldorian growth model (see Chapter 2). One of the main advantages of the Kaldorian approach is the versatility of its general framework and specific elements representing each of the demand and supply requisites, the income elasticities of demand and Verdoorn's coefficient, respectively. Understanding how each of these change across firm size classes can reveal the role of demand and supply in the development traverse. Such an approach has the additional advantage of casting light on the foundations of these elements, contributing to fill a gap in this literature. It also improves its policy prescriptions, as Chapter 9 will show.

6.3.1. The intra-sectoral demand elasticities

As presented in the second chapter, the demand elasticities can be estimated directly from the following demand function:

$$Q_j = P^{E_p} Y^{E_y} \qquad (6.5)$$

where E_Y is the income elasticity of demand, E_p the price elasticity of demand, and Q the demand for the output of each of firm size classes in the database, i.e., $j = [NSC-1, \dots, NSC-5]$. Taking logarithms of equation (6.5), it becomes:

$$ln\ (Q)_{it} = \beta_0 + \beta_1 ln\ (Y)_{it} + \beta_2 ln\ (P)_{it} + \beta_3 X_{it} + u_{it} \tag{6.6}$$

Where the subscript i represents the sectors and t is time. β_0 is a constant, β_1 the income elasticity, β_2 the price-elasticity, X_{it} is a group of control variables which include sectoral, country and year dummies, and u_{it} is the error term.

Table 6.3 reports the results for the estimation of Equation (6.6) for each firm size class adopting fixed-effects, which capture the sectoral specific effects. Since a volume index is not available in the database, the income elasticities are estimated without controlling for size-specific prices. As a way to reduce the potential bias of the estimation, the approach considers each country's sector to be an idiosyncratic sector, so that the hypothesis of homogeneity of prices needs to hold only at the specific sector in a country and not across countries. Besides, the multinational country-sector panel considerably increases the number of observations available, improving the efficiency and consistency of the regressions.

Several different fixed-effects panel data methods, including FE-GMM, IV-FE and the System GMM approaches of Blundell and Bond (2000) are reported[162]. The estimated coefficients are highly significant and stable at different specifications, indicating a good adjustment of the model to the data. This is confirmed by the highly significant F statistics. The coefficients are significant at 1% confidence level. Altogether, smaller businesses (NSC-1 to 3) present a significantly higher elasticity compared to larger firms (NSC-4 and 5).

The first column of each size class depicts the results for the specification with lags of the explanatory as instruments and 2-year averages to reduce the temporal correlation of the data[163]. Columns (ii) report the results for the model with the lagged income and logarithms of human capital and population as instruments[164], and columns (iii) the model with 2-year temporal dummies, added to control for the autocorrelation found in the AR statistic of the previous model.

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[162] The latter allows the inclusion of both (i) the lagged endogenous variable, to capture convergence effects, and (ii) the lagged exogenous variables, that act as an instrument (see Appendix 3 for a further discussion).

[163] Estimates with traditional 5-year averages deliver the same conclusions but compromises the statistical power by reducing the degrees of freedom of the estimation.

[164] All control variables were drawn from the Penn World Table 9.0.

Table 6.3 - Income elasticities by size classes: panel data estimation (1990-2007)

Variables	NSC-1			NSC-2			NSC-3			NSC-4			NSC-5		
	IV-FE	SYS-GMM	SYS-GMM	IV-FE	SYS-GMM	SYS-GMM	IV-FE	SYS-GMM	SYS-GMM	IV-FE	SYS-GMM	SYS-GMM	IV-FE	SYS-GMM	SYS-GMM
Log (output)	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)
Log(income)	1.22***	1.098***	0.974***	0.87***	1.039***	1.026***	1.130***	1.082***	1.014***	1.058***	0.977***	0.929***	0.621***	0.958***	0.894***
	0.044	0.0984	0.0415	0.038	0.126	0.0388	0.0353	0.118	0.040	0.033	0.093	0.036	0.039	0.0952	0.053
Constant	-9.6***	-8.13***	-6.66***	-5.4***	-7.699**	-7.46***	-7.96***	-7.43***	-6.48***	-6.08***	-5.11***	-4.33***	0.334	-4.04***	-3.17***
	0.5574	1.2364	0.5128	0.49	1.6238	0.4898	0.4545	1.5126	0.5094	0.4398	1.2018	0.452	0.515	1.215	0.652
N	4258	5337	5337	4333	5425	5425	3819	4921	4921	3725	4806	4806	3391	4330	4330
R^2	0.550			0.557			0.5947			0.4926			0.418		
corr	-0.33			0.106			-0.2337			-0.3115			0.200		
F		124.73	85.26		68.08	98.38		83.70	93.66		108.57	89.44		101.39	42.25
sargan		1500	1600		4000	94.53		2500	101.94		4800	35.75		1500	35.53
sarganp		0	0		0	0		0	0		0	0.216		0	0.1548
hansen		143.82	129.13		123.8143	89.25		115.46	105.91		122.73	122.71		112.24	99.39
hansenp		0	0		0	0		0	0		0	0		0	0
chi2	120000			160000			260000			400000			360000		

Notes: Variable dependent: log(output). *p<0.1, **p<0.05, ***p<0.01. Year dummies omitted.

Source: Author's own elaboration (data from SDBS)

The higher average coefficient for smaller firms (NSC-1 to NSC-3), compared to larger ones (NSC-4 and NSC-5), indicates an important (and unaccounted) influence of demand on the intra-sectoral trajectory. The differences indicate that the demand stimulate the de-concentration of sectors. I.e., the output of smaller firms grows at a much faster pace compared to larger ones as income grows. In the former, the estimated elasticities are higher than 1, i.e., the output of these firms increases by more than 1% as income grows 1%. For the latter, the output is relatively inelastic[165].

The results indicate a fundamental role for the demand in the sectoral development traverse and may explain the evidence presented in the previous sections that the market-structure de-concentrate after a certain level of development is reached. That is, the second (and unexpected) half of the development traverse might be the result of the demand constraints to the process of sectoral growth.

It is important to note that the income elasticities reveal singular characteristics of the dynamics of the demand component. Different responses of demand in face of income changes prompt divergences in firms' profitability, investment and patterns of growth. These differences indicate that firms of different size classes face different demand curves, which can be explained by different market niches or quality of the production. The causes of these divergences, however, are still not fully understood in the literature, especially in the Kaldorian tradition, which has never explored the intra-sectoral level of analysis.

6.3.2. Returns to scale and Kaldor-Verdoorn's law

Kaldor's (1966) inaugural lecture at the University of Cambridge represented the starting point of a long tradition on the investigation of returns to scale in manufacturing. As Chapter 2 briefly introduced, different versions of Verdoorn's Law are found in the literature, which tends to conclude for substantial increasing returns to scale in manufacturing. The results are generally robust to estimation methods and levels of levels of aggregation of the data, period under investigation and unit samples. Notwithstanding, the foundations of the phenomenon have historically received little attention. Much of it due to the fact that the law was originally developed as a macroeconomic stylised fact of growth. Only recently, Romero (2015) investigated whether the characteristics of

[165] The estimation of equation (6.6) for two aggregated size groups, NSC-1-3 and NSC-4-5, reveal a coefficient around 1.07 in the first and 0.9 in the second.

goods produced in different industries influence the degree of returns to scale, showing that the explanation might be at the supply-side, i.e., level of technology of the product.

This section investigates the level of increasing returns across firm size in manufacturing branches. According to Britto (2008), regardless of the source of the increasing returns (internal, external, dynamic or static), economies of scale should still be verified at the firm-level[166]. To date, however, Verdoorn's law has never been tested at the intra-sectoral level.

6.3.2.1. The model and estimation procedures

Verdoorn's law, in its dynamic demand-side version, describes a relationship between output growth and productivity growth, with the causality running from the former to the latter. Retrieving Equation (2.4):

$$q_i = \rho + \lambda y_i \qquad (6.7)$$

where q_i, ρ and y_i are the rate of growth of productivity, autonomous productivity, and total output of firm i, respectively. Equation (6.7) assumes the stability of the capital-output ratio ($k = y$), which is known as one of Kaldor's stylised facts of growth.

Since productivity growth is definitionally equal to the growth of output minus the growth of employment, i.e., $q_i = y_i - l_i$, the Verdoorn law may also be expressed as:

$$l_i = \gamma + \beta y_i \qquad (6.8)$$

In spite of the simplicity of Kaldor's original formulations, the estimation of Verdoorn's law has been subjected to a number of empirical criticisms over the years (McCombie, Pugno and Soro, 2002). According to Wolfe (1968), the exclusion of the growth rate of capital stock as a determinant of labour productivity growth in Equation (6.7) creates a bias in the estimates. Knowing the potential effect of capital accumulation on productivity growth, Kaldor (1967) explicitly included the investment-output ratio as a proxy for the growth of the capital stock. A different specification of the law, which includes the variable of capital stock, is found in Fingleton and McCombie (1998):

[166] As a way to prove it, the author estimated the firm-level Verdoorn coefficient of the Brazilian economy using a multi-level econometric model. The results were robust and compatible with the literature.

$$l_i = \gamma + \beta y_i + \tau k_i \qquad (6.9)$$

The adoption of TFP growth (tfp_i) instead of employment or labour productivity as the regressand, also addresses the problem. This approach also avoids multicolinearity between the growth rates of output and capital stock (Romero, 2015). The Verdoorn coefficient, in this case, can be derived directly from the production and technological progress functions as a number of authors have recently demonstrated (Roberts, 2007; Angeriz, McCombie, and Roberts, 2009; Romero, 2015)[167].

$$tfp_i = \beta_0 + \beta_1 y_i + \beta_2 G_i \qquad (6.10)$$

where G_i is the technological gap between sector i and the leading sector. G_i captures the convergence of the productivity, i.e., the effect of technological diffusion.

The estimation strategy should explicitly account for three problems: (i) the unobserved country and industry fixed-effects (FE); (ii) the potential endogeneity problem arising from the simultaneity between productivity growth and output growth, and between productivity growth and some of the controls, especially the lagged technology gap[168]; and (iii) the potential autocorrelation, which requires separating long-term effects of demand growth on productivity growth from short-term business cycle fluctuations (Okun's law).

The first problem is tackled with the use of the Two-Step Feasible Efficient Generalized Method of Moments (GMM) estimator with fixed-effects (Baum *et al.*, 2007). This enables the capturing the effects of observed and unobserved fixed-effects with the introduction of both time and sector

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[167] That is,

$$y = \gamma + v(ak) + v(1-a)l$$

Where v= degree of increasing returns.

$$\left(\frac{1}{v}\right)y = \frac{1}{v}\gamma + ak + (1-a)l$$

$$ak + (1-a)l = -\left(\frac{1}{v}\right)\gamma + \frac{1}{v}y$$

$$y - ak - (1-a)l = tfp = \frac{1}{v}\gamma + \left(1 - \frac{1}{v}\right)y$$

Hence, the equation for the Verdoorn law using TFP is

$$tfp = \frac{1}{v}\gamma + \left(1 - \frac{1}{v}\right)y$$

[168] Rowthorn (1975) argued that employment growth should be the explicatory and if so, even using instruments, the results suggest constant returns to scale. This issue still has not been resolved. See Magacho and McCombie (2018).

dummies in the estimation. The endogeneity problem is addressed with the 'Difference' and 'System' GMM approach of Blundell and Bond (2000). The latter enables the inclusion of the lagged endogenous variable among the estimators. It employs a system of equations in levels and differences to estimate the parameters where lags of the variables are used as instruments. Non-observable fixed-effects are controlled via differencing (Roodman, 2009). Finally, the third problem is dealt by taking temporal averages in order to smooth business cycles fluctuations. In this study, since the time-spam is relatively short, 2-year averages are adopted[169]. Alternatively, the problem can also be tackled by introducing one-period lags of the variables into the regression model, as proposed by Millemaci and Ofria (2014).

A final note on the methodology, this study opted for estimating the law for the whole sample of countries and sectors jointly, using robust panel-data methods. This strategy increases considerably the number of observations available, improving the efficiency and consistency of the estimates (Romero, 2015). As a consequence though, the estimates should not be read as the original Verdoorn's Law, but a mix between it and Fabricant's (1942) Law[170]. As shown by Salter (1960), however, the results are similar for both.

6.3.2.2. The TFP measure

The growth rate of TFP is defined as $tfp = y - tfi$, where $tfi = \alpha k + (1-\alpha)l$ is the growth rate of Total Factor Inputs (TFI) and α represents the capital-labour ratio. That is:

$$tfp_{ijt} = ln\left(\frac{Y_{ijt}}{Y_{ijt-1}}\right) - \frac{1}{2}\left(\alpha_{ijt} - \alpha_{ijt-1}\right) \cdot ln\left(\frac{K_{ijt}}{K_{ijt-1}}\right) - \left(1 - \frac{1}{2}(\alpha_{ijt} - \alpha_{ijt-1})\right) \cdot ln\left(\frac{Y_{ijt}}{Y_{ijt-1}}\right) \qquad (6.11)$$

A first empirical concern is with the physical capital stocks, which are not available in either of the databases adopted in this study. The capital stock is thus constructed by perpetual inventory method. The initial value of the capital stock for a specific country-sector is defined as $I_{to}/(g+d)$, where g is calculated as the average geometric growth rate for all available data of the investment

[169] Five-year averages were also tested without much effect on the parameters estimated, even though the statistical power is significantly reduced by the decrease in the degrees of freedom.
[170] The difference between the two is that the latter assesses the relationship between output growth and productivity growth across industries, while the former carries out the same assessment across countries.

series for the country-sector. The depreciation rate (d) is assumed equal and constant at 6 percent, as in Hall and Jones (1999)[171].

The above TFP measure has important limitations. The first concerns the reconstitution of gross investment by perpetual inventory. Ideally, the inventory would require both longer time series – for the average rate of service life of capital goods range between 12-30 years – and constancy in the units (Williams, 1998). However, even if balanced data with a larger time-spam were available, there would remain a certain level of scepticism with the measure, because changes in the business cycle can transmit the effect of short-term fluctuations to the final series (Miller, 1990). Moreover, knowledge on the characteristics of production, as specific retirements of capital by sector, region and firms would be necessary (Costa and Marangoni, 1995). Even though the simpler approach taken here can create a bias in the measure, the results seem consistent with other productivity measures, as Table 6.4 shows.

Table 6.4 - Summary statistics: productivity growth rates

Variables	N	Mean	SD	Percentiles	
				10%	90%
tfp	410	0.023	0.182	-0.180	0.214
y	3391	0.027	0.231	-0.146	0.199
Δ value added	849	0.012	0.259	-0.224	0.240
ΔL	3376	-0.018	0.206	-0.159	0.114
Δ (VA/hours worked)	203	0.079	0.191	-0.102	0.269
Δ(Y/L)	3391	0.046	0.163	-0.085	0.185

Source: Author's own elaboration (Data from the SDBS)

Another practical problem in the calculation of Equation (6.6) concerns the fact it requires the use of value added, which is largely incomplete in the SDBS database. Indeed, less than 25% of the data for all units are available for the variable in the database. In contrast, the database reports 66% and 85% of the information for the gross output and employment, respectively.

Finally, the TFP growth measure can introduce endogeneity to the estimation of the Verdoorn coefficient because both require the growth rate of gross output. The literature presents a few alternatives to circumvent this problem. Firstly, TFI can be used as a proxy for TFP. Another option is

[171] Provided the investment series is limited (also the reason why this study adopted labour productivity as prime measure of productivity), the number of degrees of freedom of the estimations are severely reduced with the tpf measure.

to change the specification of the law to introduce the lag of the endogenous variable and estimate it with GMM methods. Both alternatives were tried.

The summary statistics of the productivity growth rates presented in Table 6.4 show that even though the number of missing information is extremely high for the TFP measure, the values of the variable are within a reasonable range, being directly comparable to the labour productivity measures (Δ(Y/L) and Δ (VA/hours worked)) and also to the output measure (y). The correlation between these are above 90%.

6.3.2.3. Results

Table 6.5 shows the results of the estimation of equation (6.10) using FE and System-GMM. The Verdoorn coefficient is significant at the 1% confidence level for all specifications and the parameters are close to Verdoorn's (1949) and Kaldor's (1966) estimations, around 0.5. That is, a 1% rise in the growth of output increases TFP growth by 0.5 percentage points.

Table 6.5 - Dynamic demand-side Kaldor-Verdoorn's Law: panel data estimation, country-size class (1990-2006)

Variable tfp	FE (i)	SYS-GMM (ii)	SYS-GMM (ii)
y	0.5255***	0.5729***	0.5729***
	(0.0562)	(0.0278)	(0.0248)
tfp_{-1}		-0.0306	-0.1698
		(0.0348)	(0.1586)
y_{-1}			0.0886
			(0.0872)
Constant	0.0422***	0.0128*	0.0099
	(0.0048)	(0.0059)	(0.0065)
N	841	615	615
R^2	0.5701		
rmse	0.3671		
corr	0.0649		
F	87.3902	209.7559	123.4019
Sargan		155.678	226.5196
Prob > chi2		0	0
Hansen		29.4996	27.3261
Prob > Z		0.2019	0.1991

Notes: Gap, L1.gap and Year dummies omitted in columns (iii) and (iv).
Standard deviations in parenthesis. *p<0.1, **p<0.05, ***p<0.01
Source: Author's own elaboration (Data from the SDBS)

The figures are, however, lower than recent estimations (Angeriz, McCombie and Roberts, 2008; Alexiadis and Tsagdis; 2010; Romero, 2015). Possibly, the answer is in the fact the firm-level estimation of the parameter cannot account for all sources of increasing returns in manufacturing, especially static and dynamic externalities. This would be in accord with Kaldor's expectations.

Column (ii) reports the estimation using SYS-GMM and including the lag of the productivity growth in order to capture the adjustment between short and long-term productivity growth rates as proposed by Dixon and Thirlwall (1975). Column (iii) also includes the lagged output growth to capture the adjustment between short and long-term output growth rates. None of these were significant, being the Verdoorn coefficient highly stable.

Robustness tests corroborate the results in all the estimations. The Sargan-test reported for SYS-GMM estimations reject the null hypothesis of over-indentified restrictions in the instruments. Also, the 'Arellano-Bond' AR-test for autocorrelation did not reject the null hypothesis of no autocorrelation in any of the regressions at the 5% significance level, while Hansen's J test did not reject the null hypothesis of the validity of the instruments at the 5% significance level.

Table 6.6 reports the results of the estimation of Kaldor-Verdoorn's law by size class (Equation 6.10). Columns (i) are for the more parsimonious specification estimated by FE and columns (ii) and (iii) report the SYS-GMM estimations of more complete models.

The table shows a number of important results. First, the Kaldor-Verdoorn coefficient is significant for all size classes. Secondly, the estimates of parameters increase with firm size (from NSC-1 to NSC-4), which corroborates the evidence in the previous section. The size classes differences in the estimates are independent of controls, lags and instruments included. One interesting result is that the coefficient for the NSC-5 firm class is lower than the coefficient for the NSC-4 firm class in estimations (ii) and (iii). Wald tests confirm the statistical difference at 1% level of confidence. This indicates that the returns to scale increase with firm size, but the technological benefits of expanding the business reduces for large firms, justifying the 'investment restraint' hypothesis (Nelson and Winter, 1982).

Table 6.6 - Dynamic demand-side Kaldor-Verdoorn’s Law by size class: panel data estimation (1990-2007)

Variable	NSC-1			NSC-2			NSC-3			NSC-4			NSC-5		
	FE	SYS-GMM	SYS-GMM	FE	SYS-GMM	SYS-GMM	FE	SYS-GMM	SYS-GMM	FE	SYS-GMM	SYS-GMM	FE	SYS-GMM	SYS-GMM
tfp	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)
y	0.49***	0.46***	0.50***	0.49***	0.49***	0.47***	0.49***	0.53***	0.53***	0.51***	0.70***	0.70***	0.65***	0.63***	0.64***
	0.084	0.0647	0.0649	0.0768	0.0698	0.0778	0.0455	0.0701	0.0574	0.0607	0.1238	0.1055	0.0529	0.0452	0.0675
Log(Gap)		0.0001	0.1319		0.0001	0.198*		0	-0.0001		0.0003	0.0006		0.0001	-0.0003
		0.0001	0.0001		0.0001	0.0001		0.0002	0.0003		0.0003	0.0004		0.0002	0.0002
tfp_{-1}		-0.1853	-0.34***		-0.129	-0.339*		-0.0946	-0.4097*		-0.0468	-0.3624		-0.1354	-0.17
		0.1059	0.0879		0.0831	0.1346		0.1	0.1762		0.0781	0.2636		0.0847	0.1313
y_{-1}			0.0785			0.0856			0.2600**			0.2472			0.0305
			0.0127			0.0442			0.0884			0.2073			0.09
Constant	0.0024	0.0157	0.0161	0.012***	0.0215*	0.0243	0.0079***	0.006	0.0047	0.0087*	0.0071	-0.0075	0	0.0104	0.0195**
	0.003	0.013	0.015	0.0033	0.015	0.03	0.0013	0.006	0.0095	0.0039	0.0071	0.0131	0.0019	0.0104	0.0069
N	563	339	339	554	331	331	589	375	375	408	251	251	410	277	277
R^2	0.2941			0.2466			0.3015			0.6089			0.4965		
rmse	0.2543			0.2036			0.1586			0.0755			0.1223		
corr	-0.0122			-0.1368			0.0372			0.2242			-0.047		
F	34.23	17.95	14.26	41.67	18.62	11.77	114.68	20.74	27.24	70.34	10.90	23.45	151.59	65.51	24.68
Sargan		143.47	143.12		146.11	140.74		90.81	290.53		8214.48	9156.9		66.29	564.60
Prob > chi2		0	0		0	0		0.0001	0.0001		0	0		0.0332	0.0292
Hansen		49.83	46.58		53.59	49.42		53.79	44.63		48.43	50.34		46.49	43.78
Prob > Z		0.361	0.4071		0.236	0.3008		0.2304	0.4871		0.4149	0.2701		0.4934	0.5232

Notes: *p<0.1, **p<0.05, ***p<0.01. Year dummies omitted.

Source: Author's own elaboration (Data from the SDBS).

Moreover, the coefficients are compatible with the logistic (S) shape proposed for the technological progress function. The final inverted-U shape trajectory is thus explained both by the influence of demand on the sectoral traverse (decreasing income elasticities in firm size)[172].

Among the lags and controls, one should highlight the previous TFP growth, which is negative and significant for the first 3 firm size classes (NSC-1-3). This is possibly capturing short-term inertial growth in productivity, stemming from ongoing increases in productivity. The technological gap variable was only significant in one estimation, in line with Romero's (2015) findings.

Regarding the consistency of the estimations, again the results for the AR test did not reject the null hypothesis of no serial correlation in the error term. Also, Sargan test shows that the instruments and their subsets are valid, and Hansen's J test that the correlation between the instruments and the fixed-effects are not statistically different of zero[173].

The first column of Table 6.7 depicts the result of the estimation of Equation (6.9). The results are all significant, profiting from a more complete database on the variables, especially labour productivity. The estimates, however, are against the initial expectations.

[172] Chapter 5 showed that there is an increment in the costs of intermediate inputs as the firm reaches a large size, which can be explained by demand at higher levels of development.

[173] In all the SYS-GMM regressions the number of instruments was kept low to avoid spurious significance due to instrument proliferation (Roodman, 2009). The number of lags adopted in each model was guided by the analysis of the validity of the instruments, following the Arellano-Bond AR Test and the Hansen J Test. Attention was also paid to the stability of the results found with different lags.

Table 6.7 - Dynamic demand-side Kaldor-Verdoorn's Law by size class: panel data estimation (1990-2007)

Variable	NSC-1		NSC-2		NSC-3		NSC-4		NSC-5	
	Dependent: ΔL	Dependent: ΔKFP	Dependent: ΔL	Dependent: ΔKFP	Dependent: ΔL	Dependent: ΔKFP	Dependent: ΔL	Dependent: ΔKFP	Dependent: ΔL	Dependent: ΔKFP
	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)
y	0.2541***	0.6711***	0.3506***	0.7674***	0.3843***	0.9002***	0.3998***	0.9687***	0.5206***	0.9599***
	0.0484	0.0835	0.0263	0.0558	0.0431	0.0663	0.0296	0.043	0.0444	0.083
Log(investment)	0.0019	0.0001	0.0067*	0.0001	-0.0005	-0.0002	0.0069**	0.0004	0.0088**	0.0004
Log(GAP)	0.0036	0.0001	0.0031	0.0001	0.0035	0.0002	0.0022	0.0004	0.0029	0.0003
L1.y	0.0687	0.3028**	0.2718**	0.2051	0.3477***	0.1084	0.1139	0.4235***	0.1532	0.4157**
	0.0677	0.1064	0.0909	0.1305	0.0852	0.0883	0.0889	0.1141	0.1284	0.1509
L1.ΔL	-0.1495	-0.4357***	-0.8073**	-0.2725	-0.8739***	-0.1103	-0.1535	-0.4081***	-0.2377	-0.4596**
L1.ΔK	0.196	0.0911	0.2458	0.1689	0.2543	0.0853	0.2051	0.1197	0.239	0.1587
Constant	0.0053	0.0162	-0.018	0.0269*	-0.0079	-0.0038	-0.0516***	-0.0119	-0.0994***	0.0008
	0.0147	0.0145	0.0107	0.0116	0.0165	0.0072	0.0128	0.0061	0.023	0.008
N	1735	450	1839	542	1805	590	1730	420	1546	459
F	10.7447	40.9555	65.7518	50.2518	28.7195	44.0202	49.3257	141.423	40.1614	29.726
Sargan	118.4994	243.2396	53.8934	221.048	110.432	6 123.724	383.9815	8 161.6	174.2774	343 130.2303
Prob > chi2	0	0	0.0003	0	0	0	0	0	0	0
Hansen	36.2016	60.6725	21.2509	69.1472	27.1352	78.1738	32.8119	56.9434	27.3958	64.1129
Prob > Z	0.0393	0.4877	0.5658	0.2777	0.2503	0.0943	0.0844	0.6907	0.2395	0.4373

Notes: Dependent: tfp growth rate. *p<0.1, **p<0.05, ***p<0.01. Year dummies omitted.

Source: Author's own elaboration (Data from the SDBS).

Since the TFP measure is generated by the weighted shares of capital and employment productivity, and the estimation of (6.10) revealed a logistic cross-size pattern, one would expect a decreasing pattern in the estimation of (6.9), that is, that labour requirements were decreasing with size. In spite of it, columns (i) show a clear cross-size exponential pattern (the coefficient is especially high the class of large firms). Furthermore, the elasticities are much smaller than the ones estimated with the TFP measure.

These contradictory results inspired the estimation of the Verdoorn's law using and index of capital productivity instead of TFP[174]. The results of the estimation of the law with capital productivity only (hereby KFP) are reported in Columns (ii). The estimates resemble the ones reported in Table 6.8, with the exception that the level of the coefficient is much higher and the difference between the coefficient of the NSC-4 and NSC-5 are not statistically different one from the other.These findings explain both why [the weighted average presented by] the TFP resulted in smaller coefficients, and the quadratic cross-size evolution when using the TFP in the estimation[175]. Therefore, these apparently contradictory results actually reinforce the previous findings, showing that the technology alone furnishes incentives for the firm to grow logistically, while the labour requirement forces businesses, especially large ones, to end the continuous expansion of their output.

In summary, the tests reported in this chapter are an important contribution to the Kaldorian literature. More than demonstrating that Verdoorn's law can explain the dynamics of the supply side at a disaggregated analytical perspective, it shows that labour and capital actually furnish distinct marginal incentives to the production process.

6.4. Concluding remarks

This chapter showed that, contrary to the current Evolutionary paradigm, to consider firm size as a key element in the process of sectoral development is not antithetical with the notion of technological regimes. Such a perspective has two important implications: (i) it explains why the

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[174] The lag of the labour productivity was included as a control.

[175] It is important to note that the estimations for the two versions of the law are very distinct. In one case the growth of labour employment is used and the sample of data is much bigger (columns (i) in Table (6.8)), whereas in columns (ii) of this table, the growth of the capital productivity is measured by subtracting the capital productivity growth rate from the growth rate of the value added, with a much smaller sample. A version of the law as originally proposed by Verdoorn (1949), with labour productivity as dependent variable was also estimated and results and patterns are similar to the ones reported in columns (i), which is evidence that the findings are consistent in subsamples of the data and with different versions of the law.

empirical literature on the relevance of firm size for growth and technology change is so inconclusive; and (ii) it shows why trajectories may diverge within the same technological regime.

The analysis showed that the difference between the predicted and actual response in the intra-sectoral development trajectory is explained by the influence of the demand, which blends with the 'technological incentives' to define the final shape of the market-structure. As shown, the income elasticity of demand is inelastic for large firms (NSC4-5) and elastic for small firms (NSC1-3), being especially low in NSC-5 firms. This indicates that small businesses are benefited as the country increases its income level (this is specially marked at the highest levels of income). This phenomenon occurs against the technological incentives, which largely favour larger businesses. Ultimately, as demonstrated by the firm-level Verdoorn, the 'S' trajectory would prevail if the sectoral development traverse was determined purely by the technological aspects (see the KFP estimation).

This Chapter makes a number of contributions to the economic literature, especially tor the Kaldorian and Schumpeterian growth theories. First, it reinforces the importance of both the demand and supply factors for growth. Secondly, the approach confirms the versatility of the Kaldorian parameters in growth analyses. Finally, the seminal estimates of both the demand elasticities and the Verdoorn's law across firm sizes groups provide some much needed foundations for the Kaldorian framework. The implications of the approach are further explored in Chapter 9.

7 Structural sophistication and patterns of specialisation: an investigation of the inter-sectoral development process

7.1. Introduction

This chapter switches the focus once again to the inter-sectoral analytical level and explores relationship between manufacturing composition and the process of economic development. Following the meso-macro Evolutionary literature explored in Chapter 1, growth is defined as an ordered process of accumulation of knowledge and learning, where different sets of capabilities are necessary for the production of different goods. The results show that the process of development involves both the 'absolute diversification' of the productive structure as well as a 'relative specialisation' in more sophisticated/rare products.

Among the contributions of this chapter, one may highlight the following: (i) it deepens the discussion concerning the fit of the Evolutionary theory to explain the process of industrial development; (ii) it seminally adapts the 'method of reflections' for the analysis of the productive structure instead of trade composition[176]; (iii) it typifies and brings new evidence on the connections between patterns of specialisation and growth dynamics.

The rest of the chapter is organized as follows. Section 7.2 discusses the relationship between patterns of specialisation, industrial transformation and growth in the economic literature. Section 7.3 summarises the theoretical links between capabilities, patterns of specialisation and growth before introducing the notion of 'economic complexities' and 'structural sophistication'. Section 7.4 discusses the application of the method of reflections to the UNIDO database and compares the results with trade-data studies. Section 7.5 estimates the relationship between growth/income level and structural sophistication in a large panel for different samples and adopting different perspectives. Section 7.6 concludes the chapter by reviewing its contributions.

[176] Proposed by Hausmann *et al*. (2007), all previous applications adopt trade data in their analyses. There are advantages and disadvantages in working with each type of data. International trade data are more reliable and ubiquitous, but as long as imports and exports depend on the openness level and several other country macroeconomic, political and institutional variables, they can prompt a false perspective of the country's real productive structure.

7.2. Patterns of transformation and growth: a brief review

The Structuralism pursues a general pattern of transformation to explain the [structural] dynamics of the development process. As argued,

> *"[t]he existence of common, transnational factors, and a mechanism of interaction among nations […] produce some systematic order in the way modern economic growth can be expected to spread around the world"* (Kuznets, 1959 p.170).

Chenery (1960) lists five 'universal factors'[177] leading to uniform patterns of industrial transformation, which, however, are to be seen only at the macroeconomic level. O'Brien and Keyder (1978) suggest a multiplicity of ways for a country to industrialise without dismissing a broad transition pattern[178].

A number of stylised facts of the transformation process emerge from these typologies[179]. Cross-country comparisons show, for instance, that in the process of development labour flows from agriculture to services and, to a lesser extent, to manufacturing. Capital shifts are less pronounced, reflecting variations in rates of productivity growth and factor proportions among sectors (Chenery and Syrquin, 1986). At higher levels of income, manufacturing loses its share in the output to services. Syrquin (1988) argues that the share of food in consumption decreases, given Engel's law, while the share of resources allocated to investment sectors rises (Houthakker, 1957). Also, the use of service and manufacturing intermediates tends to rise, while the share of primary products used as intermediates declines[180]. According to Hoffmann (1958), much of the dynamics of the growth process depends on the shift of inputs and outputs from consumer goods (consumption) to producer goods (investment).

In the last 30 years, both globalisation and the acceleration of the process of technical change contributed to increase the intra-industry structural transformation (Fagerberg, 2000). This is

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[177] These include, among others: (1) technological knowledge; (2) similar human wants; (3) access to the same markets for imports and exports; (4) the accumulation of capital as the level of income increases; (5) the increase of skills, broadly defined, as income increases.

[178] Such typologies usually differentiate, among other elements, between the country size, level of income, existence of natural resources (Chenery, 1973), level of openness/trade orientation (Syrquin, 1988).

[179] Among the authors who published summary lists of the recurrent patterns of the transformation, one should mention Kuznets (I966), Chenery and Syrquin (1975), Syrquin and Chenery (1986), Syrquin (1988), Rodrik (2007). Disaggregated industrial patterns also appear in Chenery (1960), Kuznets (1966, 1971), Maizels (1963), etc.

[180] Looking at the intermediate purchases by sector it can be said that the development process induces a more intensive use of inputs from outside the sectors (fuels, fertilisers and capital goods).

especially marked in the manufacturing sector, where a number of patterns have been catalogued over the years. Syrquin (1986, 1988), for instance, showed that as income rises, the composition of manufacturing shifts from light to heavy industries. Initially, at low income levels, the share of light industries increases as result of the increment in both import substitution and internal demand. As income grows, however, the share of heavy industries increases. This results from both increases in the intra-industry trade (as capital and intermediates goods are generally attributed to heavy industries), and in the consumption of durable goods (with high income-elasticities)[181].

Among the usual transformation narratives, Timmer and Szirmai (2000), emphasise two possibilities: the 'mushroom-process' and the 'yeast-process'. In the first, *"economic growth is characterized by continuous shifts of resources into specific dynamic sectors. [On the contrary, the latter argues that] economy-wide growth tendencies predominate"* (Ibid, pp.373). A common hypothesis is that, in the course of economic growth, labour and capital shift from less productive to more productive manufacturing branches. This phenomenon would be responsible for a 'structural bonus' (Timmer and Szirmai, 1999) derived from the reallocation of factors during the growth process[182].

Chenery and Taylor (1968) make a notable contribution to this view. They highlight the shift from early to middle and late industries. Early industries include low productivity activities (industries catering to basic domestic needs, such as foodstuff and textiles). Middle industries include intermediate inputs. Late industries are the higher productivity activities, which include investment and sophisticated consumer goods.

Ultimately, the clash between diversification and specialisation dominates the development debate, where growth appears as result of either one option or the other. The advocates of the 'specialisation argument' usually start with the Ricardian international trade theory and Hecksher-Ohlin model. The country's pattern of specialisation in international trade is always assumed a key determinant of the productive structure and growth trajectories (Syrquin, 1988). Small economies

[181] The factor intensities are what differentiate light from heavy industry, where the latter tend to be more capital and skill intensive.

[182] An opposite approach is that of the structural burden hypothesis, also known as the 'cost disease' argument of unbalanced growth, presented by Baumol (1967). This states that because of the limited potential to increase labour productivity through technological progress or capital deepening, final products industries suffer with the rise in the cost of production, as well as increasing shares in employment and nominal output.

are generally more specialised in trade[183]. Other elements such as the availability of natural resources, factor proportions and governmental policies also determine the type of specialisation. Small countries with large endowments of natural resources tend to have higher levels of specialisation. The latter also tends to industrialise in earlier development phases (at lower levels of income). In large countries, the feasibility of inward-oriented policies such as import substitution contributes to a higher level of product diversification in earlier phases.

The advocates of 'diversification argument' list a number of advantages of the diversification. Fagerberg and Verspagen (1999), for instance, emphasise the externalities trickling down from dynamic and transversal industries[184] to the remaining sectors in diversified economies. The increased versatility that diversified economies display is also highlighted, as it reduces the product dependency of products with volatile market. Some authors also argue that diversification fosters the process of structural change, creating 'scope for technological progress'[185]. According to Salter (1960, pp.9), *"a flexible structure of production is an important element in the high rate of productivity increase, for it allows an economy to rapidly redistribute its resources so as to take maximum advantage of changing patterns of technological progress"*.

In the Evolutionary tradition, diversification and specialisation are different facets of the same process. The process of industrial development requires both the diversification of the productive structure and the relative specialisation in technologically intensive sectors. This is only a relative specialisation since the technological characteristics of these sectors make the labour requirements particularly low in them. In part, "*this explains why structural change — in a pure accounting sense — was more important for productivity growth previously than it appears to have been more recently*" (Fagerberg, 2000, pp.409). The next section explores the modern macro-evolutionary perspective on the topic.

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[183] The main determinant of the weight of trade in an economy is its size (Deadorff, 1984).
[184] Transversal industries are those which the product are important at other sectors of the economy, e.g., electronics, computer science, etc.
[185] Hausmann and Klinger (2006, pp.1) argue that '*the assets and capabilities needed to produce one good are imperfect substitutes for those needed to produce other goods, but the degree of asset specificity varies widely. Given this, the speed of structural transformation will depend on the density of the product space near the area where each country has developed its comparative advantage*'.

7.3. The inter-sectoral process of development: the Evolutionary perspective

In the Evolutionary tradition, technological progress is a continuous [and progressive] process of learning, where knowledge is accumulated in tangible and intangible assets to be converted into innovations that increase the productivity of factors (Griliches, 1979). Based upon the same principles of variety and path-dependence, the line of research inaugurated by Hidalgo *et al*. (2007) combine methods from the network theory with structural elements to show that economic development is a process of learning how to produce more sophisticated (complex) products.

According to Hidalgo and Hausmann (2009), each product a country produces requires a large number of non-tradable inputs, or capabilities[186]. These capabilities are progressively "*embodied in the tacit knowledge of the individuals who comprise the firm's workforce*" (Felipe *et al*., 2011 p.37). Some are interchangeable and others specific. More sophisticated products require a greater number and less ubiquitous capabilities. The complexity of a product is thus a function of the required capabilities for its production, while the country's complexity, a measure of its level of development, depends on the number of capabilities locally available (Felipe *et al*., 2011).

Much of the literature is dedicated to the empirical measurement of such capabilities. As argued by the authors, although not directly observable at the meso-macro analytical perspective, these should be reflected in the trade specialisation and productive structure of the economy[187]. The subsection 7.3.1 introduces the 'method of reflections' and proposes an adaptation for the analysis of the productive structure. Sections 7.3.2 and 7.3.3 show the results of the application of the method and discuss the connections between patterns of specialisation, complexities and income level.

7.3.1. Measuring the sophistication of the productive structure: the complexity index

In the methodology proposed by Hidalgo and Hausmann (2009), the measurement of the economic complexity involves the iterative combination of trade data by country and product, where revealed comparative advantages (RCA) are used to generate two basic indexes: the 'country diversification

[186] These can be seen as the building blocks of production and range from organizational abilities to legal systems (Hausmann and Hidalgo, 2011).

[187] Hausmann and Hidalgo (2011) calculated the existence of in 23 to 80 distinct capabilities, depending on the level of disaggregation of the data.

index' and 'product ubiquity index'. These are the simplest measures of country and product complexity, respectively (Felipe *et al.*, 2011).

The diversification index is defined as the number of products produced with RCA by a country, while the ubiquity by the number of countries that produce a product with RCA. The rationale is straightforward. The larger the set of capabilities internalised, the more products with RCA produced by a country. Similarly, the greater the number of countries producing a specific product with RCA, the lesser the number of capabilities required in its production. More complex products require less common capabilities, thus the lower the ubiquity index, the higher the product complexity. Formally:

$$k_{c,0} = \sum_{p=1}^{N_p} M_{cp} \qquad (7.1)$$

$$k_{p,0} = \sum_{c=1}^{N_c} M_{cp} \qquad (7.2)$$

Where $M_{cp} = \begin{cases} 1, if\ country\ (c)\ produces\ product\ (p) with\ RCA \\ 0,\ otherwise \end{cases}$.

The subscripts c and p refer to country and product, respectively, and the number that follows represents the iteration[188]. $k_{c,0}$ is the sum of the M_{cp} for all products $p = \{1, \dots, n_p\}$ the country produces. It represents the country most basic complexity measure, i.e., the number of products produced with RCA by the country, or its level of diversification. Likewise, $k_{p,0}$ is the simplest product complexity measure, the number of countries $c = \{1, \dots, n_c\}$ producing the product p with RCA, or the product ubiquity.

Balassa's (1965) revealed comparative advantage index (RCA) is adapted for the use of production data instead of trade data. The index is calculated as the ratio of the product share in the country's output and the same share worldwide. In formal terms, with val representing the real value of the output in the sector i and country c:

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[188] In order to keep the comparative advantage element in full and privilege the actual competitive advantage displayed by the product p, the actual RCA values were also computed in place of the binary response. The results are only marginally influenced by this modification, since these extreme cases are rare (the distribution of the RCA is not statistically different from a t-student). Felipe *et al.* (2011) tested different cut-off values for the RCA (from 0.75 to 1.25), but the rank correlation between the results were superior to 0.99 for the country complexity index and 0.88 for product complexity.

$$RCA_{c,i} = \frac{val_{c,i}/\sum val_{c,i}}{\sum_c val_{c,i}/\sum_i \sum_c val_{c,i}} \quad (7.3)$$

Equation (7.3) measures the relative specialisation in the production of a specific good. In order to check the consistence of the index, two other measures of comparative advantage were tested. The first one is an index of revealed productivity advantage, calculated by replacing output by productivity in equation (7.3). The second indicator is a combination of the previous two. That is, in the calculation of the complexity indicator, k, $M_{cp} = 1$ only if both RCA indicators are bigger than one. The correlation between these alternative RCA measures is greater than 95% and the results of the complexity indicator not significantly affected by the RCA measure.

The 'method of reflections' consists of combining the ubiquity and diversity indicators iteratively by using the average value of the indicator found in the preceding iteration. Formally, as established by Hidalgo and Hausmann (2009):

$$k_{c,n} = \frac{1}{k_{c,0}} \sum_{p=1}^{N_p} M_{cp} k_{p,n-1} \quad (7.4)$$

$$k_{p,n} = \frac{1}{k_{p,0}} \sum_{c=1}^{N_c} M_{cp}\, k_{c,n-1} \quad (7.5)$$

where $n = \{0,1,\dots,n\}$ represents the number of iterations. The authors show that the resulting indicators converge to their means as the number of iterations increases. Consequently, equations (7.4) and (7.5) should be iterated until the point is reached where there is no more observable changes in the rankings of country and product complexity.

Odd and even iterations contain different information though. For each country, the even iterations ($k_{c,0}$, $k_{c,2}$, $k_{c,4}$,…) yield a measure of diversification and the odd iterations ($k_{c,1}$, $k_{c,3}$, $k_{c,5}$,…) measures of the ubiquity of goods this country produces. Similarly, for each product, the even iterations ($k_{p,0}$, $k_{p,2}$, $k_{p,4}$,…) relate to the product ubiquity and the odd-numbered iteration ($k_{p,1}$, $k_{p,3}$, $k_{p,5}$,…) with the diversification of the countries producing the good. Table 4.1 illustrates some of the iterations:

Table 7.1 - Method of reflections: first three indicators

n		Country		Product
0	$k_{c,0}$	Number of products produced with RCA by country c	$k_{p,0}$	Number of countries producing product p with RCA
1	$k_{c,1}$	Average ubiquity of the products produced with RCA by country c	$k_{p,1}$	Average diversification of the countries producing product p with RCA
2	$k_{c,2}$	Average diversification of countries with similar productive structure as country c	$k_{p,2}$	Average ubiquity of the products produced with RCA by countries producing p with RCA

Source: Felipe *et al*. (2011)

The result of successive iterations of the method of reflections is a pair of indexes, $k_{p,n}$ and $k_{c,n}$, that measure, respectively, the product and country level of complexity or sophistication in production. The higher the values $k_{p,n}$ and $k_{c,n}$ the higher the number of capabilities necessary to produce the good and the higher the number of capabilities internalised in the country.

Hidalgo and Hausmann (2009) inputted trade data extracted from the UN Commodity Trade Statistics to three different classifications: (i) the SITC rev. 4 (772 products, 129 countries); (ii) the HS classification at the 4-digit level (1241 products, 103 countries); and (iii) the NAICS at the 6-digit level (318 products, 150 countries). Felipe *et al*. (2011) worked with trade data classified at the 6-digit level from the Harmonized System (HS), which comprises 5132 products and 176 countries, also drawn from the UN Commodity Trade Statistics. Although the time period, classifications, and country samples diverge in all these studies, the results were fairly similar, indicating the robustness of the method.

The method constitutes an improvement over the original complexity methodology published in Hausmann *et al*. (2007), which combined information on income per capita, network structure and exports. By separating the information on per capita income from the information on networks and international trade, the method of reflections addresses the criticism that the original index was tautological for offering the circular conclusion that rich countries export rich-country products.

Felipe *et al*., (2011) found that the rank correlations between the complexity and traditional country-capabilities indexes, namely: the 'Technological capabilities index', from Achibugi and Coco (2004); the 'Technology achievement index', from Desai *et al*. (2002); the 'Industrial performance and Combined indexes', from Lall and Albaladejo (2002); and the 'Index of science and technology', from Wagner *et al*., (2002), are all above 0.83. The same conformity was found comparing the product complexity index with technological capabilities lists by products: specifically, the Hatzichronoglou's (1997) list of high-tech products, and Hobday's (1998) classification of complex products and systems (CoPS). They showed though that the index outperforms both for classifying a much larger group of high-tech products and allowing a classification of the products within each CoPS industry.

Finally, the method presents advantages over alternative technological capabilities methods and measures, both for its simplicity, which only requires disaggregated information on output, but also for its completeness, since it merges two separated dimensions, the product and country capabilities in the same indicator.

7.3.1.1. The complexity index

In the following we discuss the results of the application of the method of reflections to the inter-sectoral database (UNIDO) introduced in Chapter 3 and further discussed in Appendix 1. The final sample comprises 45 countries and 125 industrial sectors are considered. To enable comparisons, all gross output values were deflated by an index derived from the sectoral volume index contained in the original dataset. The final indicators reported are averages for the period between 2001-2008 as to provide a more recent picture of the level of structural sophistication (complexity) of the product and country[189].

7.3.1.1.1. Country complexity

Table 7.2 presents the 2001-2008 average of the first three country-level complexity indexes presented in Table 7.1. These were calculated yearly are ranked by the second iteration of the complexity index for the country, i.e., kc2, for the top and bottom 5 countries in the sample[190].

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[189] The average of the period helps softening year variations due to eventual misreport of the sectoral product by the countries.

[190] As discussed, more information can be obtained in higher iterations. The choice for kc2 as the measure of complexity was oriented by the relative stability of the rank in higher iterations.

Table 7.2 - Country-industrial complexity ranking: top 5 and bottom 5 countries

RANK	COUNTRY	Log AVERAGE PROD	kc0	kc1	kc2
		Top 5 countries			
1	Germany	7.29	54.00	11.84	47.48
2	France	7.34	52.42	12.72	46.96
3	United Kingdom	7.33	58.89	14.01	46.89
4	USA	7.53	52.18	12.49	46.84
5	Sweden	7.22	45.82	13.39	46.57
		Bottom 5 countries			
41	Brazil	7.00	27.00	13.07	41.81
42	Israel	7.24	20.92	13.60	41.65
43	Argentina	7.20	21.80	15.23	41.46
44	Russia	6.46	26.80	11.26	41.18
45	Qatar	6.86	16.29	15.86	40.87

Notes: The values are averages of the yearly-calculated indicators for the period 2001-2008.
kc0, kc1 and kc2 represent, respectively, the diversification index, the first and the second iteration of the complexity index.
Source: author's own elaboration (data from UNIDO)

To illustrate the differences between the iterations, compare the index for the UK and Germany. kc0 shows that the UK is a more diversified economy than Germany (meaning that it produces more products with RCA than Germany, average of 59 against 54). Does it mean that UK manufacturing is more complex than Germany's? In fact, no. As the next iteration (kc1) shows, the type of product produced by the UK is produced by other 14 countries on average, and only 12 in the case of Germany. This information is brought about by kp0, which is contained in kc1 according to equation (7.4). As long as Germany produces less ubiquitous products, the types of capabilities required in their production are more specific (advanced). This information can still be improved, though, by considering the complexity of the countries producing the same product. The next iteration (kc2), adds this information. As it uses kp1, which is the average diversification of the countries producing that product, kc2 depicts the full complexity of the productive structure of the country. The higher value of kc2 for Germany says that its industrial production is more complex than that of UK because it produces less ubiquitous products, which are produced by fewer and more complex countries (with more diversified and less ubiquitous capabilities), even though the UK presents a more diversified production.

Several other conclusions can be drawn by crossing the estimates of country complexity with income and development indicators. Section 7.3.2 shows that more developed countries present a more complex industrial structure in comparison to newly developed countries (South Korea and Ireland, for instance), while Middle East and Latin-American countries are in the last positions of the ranking[191]. The next chapter will explore the relationship between specialisation and development in depth.

7.3.1.1.2. Product complexity

Table 7.3 presents the top and bottom 5 products/sectors. The first indicator, kp0 is the number of countries producing the product with RCA. The higher kp0, the more ubiquitous are the capabilities necessary for the production of the product p. The first iteration, kp1, shows the average diversity of the countries producing the product with RCA. This is a better indicator of the number of technological capabilities necessary in its production. Higher-level iterations refine the index, bringing new information to the analysis, as detailed in Table 7.1. As further iterations only promoted marginal changes in the product complexity ranking, kp5 was chosen as the product complexity index.

To see the effect of the iterative process, consider the production of *Tobacco products* (i.d. 1600), for which only 4 out the 45 countries (on average) in sample had RCA. This means that the capabilities necessary for its production are fairly rare. The item, though, is ranked in the last position of the complexity table, 121 positions below *Medical, surgical and orthopaedic equipment* (i.d. 3311), for which more than 9 countries have RCA. This difference is explained by analysing higher iteration indexes. kp1, for instance, is almost 1/4 higher in the latter than in the first, indicating that the level of diversification of countries producing medical equipments is much higher than the diversification of tobacco producers. Kp5 ultimately represents the complexity of countries producing the good in relation to its ubiquity.

Table 7.3 brings other valuable information on the role of different sectors in the growth process. As shown, the employment shares (L_s) for more sophisticated sectors are greater than the output share (Q_s) of the same sectors. In contrast with them, the least complex products display a much bigger product share than the employment share. Interestingly enough, there is no clear relationship between the sectoral complexity and sectoral productivity. This result is in contrast with the usual

[191] It is worth mentioning that the limitations of the dataset might influence these results. In fact, countries for which production data presents the highest number of missing information are the ones with the worst indicators. Once fewer products are represented, the diversification index is smaller, making such results expected. Notwithstanding, the effect of the missing information on the index is diluted in higher iterations.

hypothesis in the transformation literature that the industrial production evolves from low-productivity to high-productivity sectors (Salter, 1988). This is especially true if one assumes that the natural process of industrial development involves the internalisation of more ubiquitous or basic capabilities before more sophisticated capabilities. This aspect will be further explored in the next chapter, but it is worth noting that this indicates that sophisticated sectors are probably more important for the external economies that they generate than for their internal economies of scale (illustrated in their own productivity level).

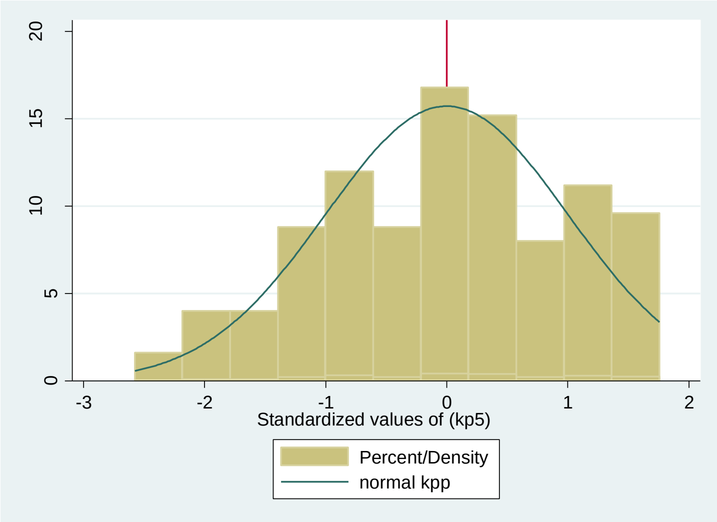
Table 7.3 - Industrial complexity ranking by ISIC sector

Rank	ISIC4	SECTOR	Prod	L_s	Q_s	kp0	kp1	kp2	kp5
		Top 5 sectors							
1	2929	Other special purpose machinery	6.978	1.24%	0.92%	8.69	49.13	12.14	45.631
2	2891	Metal forging	6.968	0.67%	0.52%	9.77	51.84	12.18	45.614
3	2893	Cutlery, hand tools , etc	6.832	0.92%	0.55%	7.15	50.95	12.42	45.604
4	3311	Medical and surgical equipment	6.907	1.02%	0.62%	9.15	48.24	12.59	45.601
5	2913	Bearings, gears and driving	7.004	0.40%	0.29%	6.92	50.08	11.82	45.596
		Bottom 5 sectors							
121	1531	Grain mill products	7.367	0.78%	1.24%	8.77	40.83	12.15	44.969
122	1514	Vegetable and animal oils and fats	7.597	0.72%	2.00%	9.54	40.67	12.00	44.957
123	2694	Cement, lime and plaster	7.334	0.76%	1.42%	12.31	39.29	12.40	44.935
124	1542	Sugar	7.408	0.87%	0.93%	6.85	41.32	11.79	44.896
125	1600	Tobacco products	7.801	0.98%	1.86%	4.31	40.42	11.07	44.837

Notes: The values are averages of the yearly-calculated indicators in the period 2001-2008. Prod = log of the average labour productivity indicator. kp0 is the ubiquity index and kp1-5 are the iterations of the product complexity index. L_s and Q_s are the average shares of labour employment and output, respectively.
Source: author's own elaboration (data from UNIDO)

Figure 7.1 shows the standardised distribution of the sectors by the complexity index. The black line helps visualising the approximate standardised normal distribution of the index. A few clusters stand out, the biggest between the average (zero) and +0.5 standard deviation value. The second and third clusters are around -1 standard deviation and above +1 standard deviation of the average. There is a clear separation between high complexity, average complexity and low complexity products, with each constituting a different network of interconnected sectors (Hidalgo and Hausmann, 2009). The longer left tail illustrates the point in the literature that low complexity products require more ubiquitous capabilities, being relatively unconnected to network of higher complexity products.

Figure 7.1 - Distribution of standardised values of product complexity

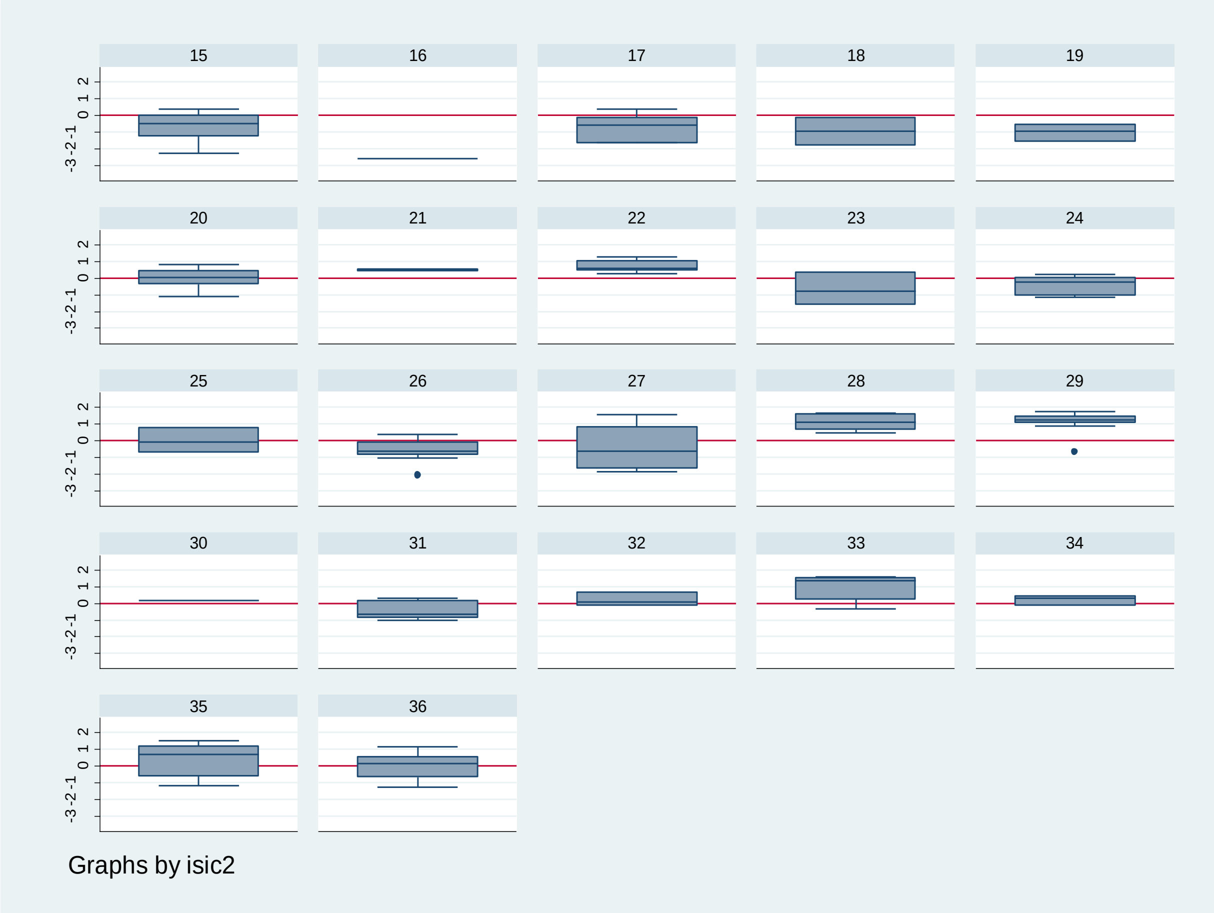


Notes: Vertical axis = percentage of data; Horizontal axis = standard deviation from the mean (zero)
Source: author's own elaboration (data from UNIDO)

Confirming previous studies (Felipe *et al.*, 2011; Hausmann and Hidalgo, 2009), high-complexity sectors are generally Machinery, Chemicals and Metal products, whereas the least complex products are mostly Raw materials, Basic Commodities and Agricultural products. However, the distribution within these industries is not clear. To see how sectors fare in the index, consider Figure 7.2, which illustrates the sectoral complexity distribution within each of the 22 2-digits ISIC sectors[192]. The more concentrated at the top of the plots (above the red line at point 0), the higher the sectoral level of complexity and vice-versa. *Basic metals sub-sectors* (id. 27) are distributed across the whole range of complexity values, indicating a huge heterogeneity within the group. Only six sectors have the average complexity of their sub-sectors above zero, most notably *Fabricated metal products* (id. 28) and *Machinery and equipment* (i.d. 29). *Tobacco products* (id. 16), *Wearing apparel and fur* (i.d. 18) and *Leather and footwear* (id. 19) are the negative highlights with all sub-sectors in groups of lower complexity.

[192] The box-plot illustrates the distribution of the data. The central blue line shows the average value in the sample. Inside the coloured box are the information within the first standard deviation. The lines outside show the minimum and maximum value found in the sample.

Figure 7.2 - Sectoral distribution of standardised values of product complexity: box-plot



Notes: Tobacco products (id. 16) and office, accounting and computing machinery (id. 30), have no sub-sectors.
Source: author's own elaboration (data from UNIDO)

As this is the first study to apply the method of reflections production database, special care should be taken in comparing the findings with the literature based on trade data. The results above are, however, highly consistent with those found in the complexity and product-space literature (Hidalgo *et al*. 2007). This proves that the method of reflections can provide good results even with a restricted database and a modified RCA index. The compatibility of the results also demonstrates that international trade specialisation is a good proxy for the country's actual productive structure.

7.3.2. Productive sophistication and industrial transformation: an empirical investigation

The complexity approach offers a viable alternative for understanding the process of industrial transformation, especially compared with the traditional models described in section 7.2. Nevertheless, some important empirical linkages between complexities, the industrial composition and income levels deserve a closer look.

Table 7.4 - 10 most complex products and their main producers

Product/Country	L_s	Q_s	Product/Country	L_s	Q_s
2732 - Casting of non-ferrous metals			2919 - Other general purpose machinery		
Austria	0.75%	0.59%	Netherlands	3.47%	2.26%
Slovenia	0.64%	0.74%	Denmark	2.95%	2.91%
USA	0.54%	0.28%	Sweden	2.92%	2.46%
Italy	0.48%	0.46%	Germany	2.62%	2.20%
France	0.46%	0.25%	Italy	2.57%	2.27%
2891 - Metal forging/pressing/stamping			2929 - Other special purpose machinery		
Singapore	2.34%	1.09%	Finland	4.23%	3.27%
Japan	1.48%	1.03%	Austria	3.12%	3.10%
France	1.40%	0.95%	Germany	2.71%	2.13%
Netherlands	1.35%	1.01%	Singapore	2.49%	1.05%
Germany	1.31%	0.95%	Korea	2.46%	1.43%
2893 - Cutlery, hand tools and general hardware			3311 - Medical, surgical and orthopaedic equipment		
Czech Republic	3.69%	3.07%	Ireland	6.67%	3.41%
Slovenia	2.94%	2.03%	USA	2.28%	1.70%
Austria	2.44%	1.75%	Denmark	2.01%	1.92%
Sweden	1.88%	1.31%	Germany	1.94%	1.06%
Germany	1.86%	1.17%	Netherlands	1.80%	1.12%
2912 - Pumps, compressors, taps and valves			3312 - Measuring/testing/navigating appliances, etc.		
Denmark	4.68%	3.73%	USA	2.30%	1.80%
Germany	1.92%	1.53%	UK	1.96%	1.60%
Ukraine	1.58%	0.70%	Slovenia	1.78%	1.29%
Netherlands	1.48%	1.23%	Sweden	1.72%	1.44%
Bulgaria	1.44%	1.52%	Germany	1.66%	1.21%
2913 - Bearings, gears, gearing & driving elements			3530 - Aircraft and spacecraft		
Germany	1.26%	0.95%	Singapore	3.11%	2.10%
Japan	0.79%	0.60%	USA	3.11%	3.17%
Singapore	0.76%	0.35%	UK	2.98%	3.51%
Sweden	0.70%	0.50%	Canada	2.95%	3.19%
Italy	0.70%	0.55%	Ukraine	2.78%	1.03%

Notes: Ls is the sectoral labour share in total employment and Os the sectoral output share in total output.
Source: author's own elaboration (data from UNIDO)

In order to understand how complexities and patterns of specialisation are connected, Tables 7.4 and 7.5 compare the information on the product complexity with the country complexity and patterns of specialisation. The first thing that is evident from the tables is the fact that the main producers of the most complex products are high-income and high-complexity countries, while the main producers of the least complex products are amongst the countries with the lowest levels of income and kc2 in the sample.

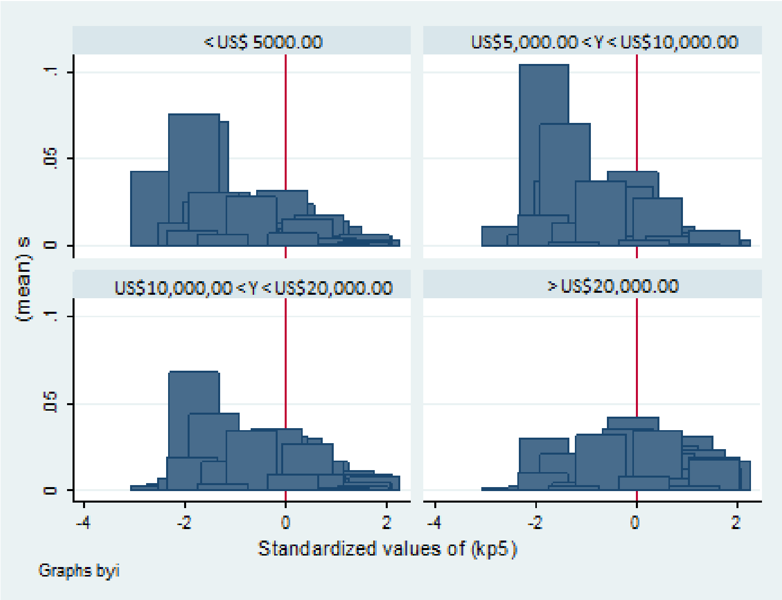
Table 7.5 - 10 least complex products and their main producers

Product/Country	L_s	Q_s	Product/Country	L_s	Q_s
1514 - Vegetable and animal oils and fats			1730 - Knitted and crocheted fabrics and articles		
Bolivia	4.31%	12.28%	Israel	6.05%	2.51%
Malaysia	2.75%	8.42%	Peru	5.93%	1.93%
Indonesia	2.65%	7.60%	Latvia	3.50%	2.23%
Ecuador	2.43%	4.06%	Argentina	3.30%	1.42%
Colombia	1.66%	2.39%	Bulgaria	2.88%	1.44%
1531 - Grain mill products			1810 - Wearing apparel, except fur apparel		
Panama	4.09%	5.71%	Qatar	35.95%	5.02%
India	3.29%	3.03%	Bulgaria	32.70%	9.72%
Bolivia	1.98%	3.05%	Morocco	32.06%	7.05%
Mexico	1.89%	2.44%	Brazil	19.37%	4.17%
Uruguay	1.81%	2.72%	Portugal	15.09%	5.89%
1542 - Sugar			2320 - Refined petroleum products		
Panama	4.68%	3.51%	Qatar	5.79%	39.90%
Ecuador	4.25%	2.01%	Bulgaria	4.20%	31.06%
India	3.42%	2.18%	Russia	3.73%	22.95%
Mexico	2.26%	1.51%	Jordan	3.11%	19.01%
Bolivia	2.10%	4.29%	Ecuador	1.99%	16.31%
1600 - Tobacco products			2694 - Cement, lime and plaster		
Indonesia	6.65%	6.52%	Israel	3.96%	5.34%
India	5.57%	0.93%	Qatar	3.12%	3.43%
Bulgaria	2.94%	6.60%	Bolivia	2.46%	3.71%
Turkey	2.31%	2.69%	Jordan	2.25%	4.70%
Argentina	1.62%	3.48%	Russia	1.74%	1.53%
1711 - Textile fibre preparation; textile weaving			2720 - Basic precious and non-ferrous metals		
Turkey	12.46%	7.97%	Russia	7.44%	14.10%
India	10.58%	5.56%	Norway	3.02%	7.90%
Indonesia	6.92%	5.56%	Bulgaria	2.02%	12.04%
Bolivia	5.85%	1.86%	Brazil	1.93%	4.34%
Ecuador	4.55%	2.23%	Canada	1.91%	3.39%

Source: author's own elaboration (data from UNIDO)

Figure 7.3 illustrates the relationship between income levels and patterns of specialisation. It depicts the employment distribution across the complexity groups for four different levels of income. The horizontal axis presents the average value of the complexity index as zero (standardised). The values in the axis are of standard deviations. Low-complexity products are on the left side and high-complexity products on the right side of the horizontal axis.

Figure 7.3 - Patterns of specialisation and complexity by level of income



Source: author's own elaboration (data from UNIDO)

The patterns of specialisation are closely connected with the country's level of income. The poorer the country, the more it specialises in low-complexity products (left of the red vertical line). Likewise, the richer the country, the more it specialises on high-complexity products. More importantly, the richer the country, the more diversified it is. Figure 7.4 illustrates the industrial specialisation by complexity level for some of the countries in the sample.

Although not reported, the skewness of the distribution reveals that high-income countries are characterized by higher shares of high-complexity products (negatively skewed) and low-income countries by even higher shares of low-complexity products (positively skewed). The cross-country distribution was found not to be normal as in Felipe *et al*. (2011).

Figure 7.4 - Patterns of specialisation and complexity by country

Notes: The vertical scales vary by countries.
Source: author's own elaboration (data from UNIDO)

Table 7.6 presents the industrial composition of the countries of the sample using five sectors, 1 to 5, increasing in the level of sophistication. s1 represents the share of employment of sectors for which the product complexity (kp5) was found to be inferior to -2 standard deviations (from the standardised average), s2 between -2 and -1, s3 between -1 and 0, s4 between 0 and 1, and s5 the share in the employment for sectors with sectoral complexity higher than 1 standard deviation. Displayed in decreasing order of structural complexity (kc2), countries on the top of the table have a much greater portion of their labour allocated in high complexity sectors. The figure is the inverse for the countries at the bottom of the table.

Table 7.6 - Industrial specialisation by level of complexity

Country	Log Income per capita	Log prod	s1	s2	s3	s4	s5	kc0	kc2	RCA1
Germany	4.48	7.29	0.49%	8.65%	26.47%	37.00%	27.39%	54	47	0.46
France	4.43	7.34	0.44%	12.09%	26.49%	36.52%	24.46%	52	47	0.43
United Kingdom	4.44	7.33	0.30%	10.83%	26.20%	37.62%	25.05%	59	47	0.50
USA	4.58	7.53	0.41%	12.00%	23.36%	36.67%	27.56%	52	47	0.46
Sweden	4.45	7.22	0.17%	11.93%	22.50%	38.61%	26.79%	46	47	0.46
Netherlands	4.52	7.33	0.86%	7.27%	23.58%	44.41%	24.42%	51	47	0.56
Finland	4.43	7.25	0.28%	10.83%	17.39%	47.32%	24.18%	46	46	0.41
Italy	4.43	7.34	0.67%	22.49%	25.38%	29.31%	22.15%	54	46	0.45
Japan	4.48	7.66	0.24%	15.62%	26.59%	37.18%	20.38%	52	46	0.43
Austria	4.48	7.20	0.28%	13.57%	26.22%	37.82%	22.22%	53	46	0.51
Denmark	4.48	7.19	0.33%	5.33%	27.15%	44.91%	22.42%	45	46	0.52
Slovenia	4.27	6.90	0.58%	19.29%	30.80%	31.96%	17.37%	52	46	0.45
Spain	4.37	7.21	0.89%	18.00%	28.97%	36.22%	15.91%	55	46	0.45
Canada	4.50	7.40	0.44%	18.52%	25.04%	35.77%	20.23%	49	46	0.47
Singapore	4.49	7.34	0.00%	7.45%	14.81%	51.73%	26.01%	34	46	0.48
Norway	4.72	7.25	0.22%	12.26%	18.28%	51.28%	18.03%	41	46	0.40
South Korea	4.29	7.35	0.46%	22.71%	25.23%	36.56%	15.05%	49	46	0.39
Mexico	4.04	7.01	3.61%	24.28%	37.97%	28.71%	5.43%	57	46	0.58
Belgium	4.46	7.42	1.16%	15.83%	30.01%	37.59%	15.41%	50	46	0.45
Australia	4.50	7.20	1.40%	22.46%	22.83%	44.81%	8.50%	46	46	0.55
Hungary	4.12	6.74	0.53%	18.62%	27.70%	38.64%	14.50%	50	45	0.42
Czech Republic	4.24	6.61	0.40%	25.98%	26.47%	32.89%	14.30%	48	45	0.74
Turkey	3.98	6.98	5.62%	43.84%	24.32%	19.85%	6.37%	42	45	0.35
Ukraine	3.73	6.12	2.49%	32.13%	18.76%	28.54%	18.08%	46	45	0.37
Portugal	4.27	7.01	0.44%	35.62%	24.77%	27.74%	11.42%	35	45	0.31
Ireland	4.53	7.40	1.19%	15.11%	24.89%	43.59%	15.31%	36	45	0.49
Malaysia	3.96	6.93	0.92%	18.89%	31.97%	41.35%	6.87%	36	44	0.31
Colombia	3.78	6.87	2.57%	36.60%	27.51%	26.90%	6.43%	51	44	0.46
Estonia	4.05	6.63	0.00%	19.55%	29.88%	41.36%	9.22%	38	44	0.59
India	3.30	6.53	10.12%	41.76%	19.96%	20.30%	7.87%	46	44	0.38
Indonesia	3.46	6.41	8.80%	40.13%	29.51%	19.16%	2.40%	44	44	0.39
Ecuador	3.71	6.78	5.64%	25.60%	43.31%	22.90%	2.55%	39	44	0.39
Bolivia	3.47	6.55	4.95%	36.43%	27.66%	28.12%	2.83%	35	44	0.42
Peru	3.70	6.76	1.82%	38.84%	23.69%	27.95%	7.71%	35	44	0.29
Panama	3.96	6.99	6.55%	29.27%	25.16%	35.38%	3.64%	29	43	0.69
Latvia	3.96	6.38	0.82%	33.34%	26.14%	31.82%	7.88%	30	43	0.35
Jordan	3.58	6.66	3.31%	28.78%	28.12%	34.62%	5.18%	34	43	0.44
Uruguay	3.92	7.01	2.87%	25.99%	30.45%	40.69%	0.01%	32	43	0.56
Morocco	3.41	6.74	1.98%	50.13%	24.61%	19.41%	3.88%	31	43	0.27
Bulgaria	3.90	6.25	3.19%	55.66%	20.54%	15.28%	5.32%	29	43	0.56
Brazil	3.84	7.00	0.86%	50.85%	32.67%	14.91%	0.71%	27	42	0.81

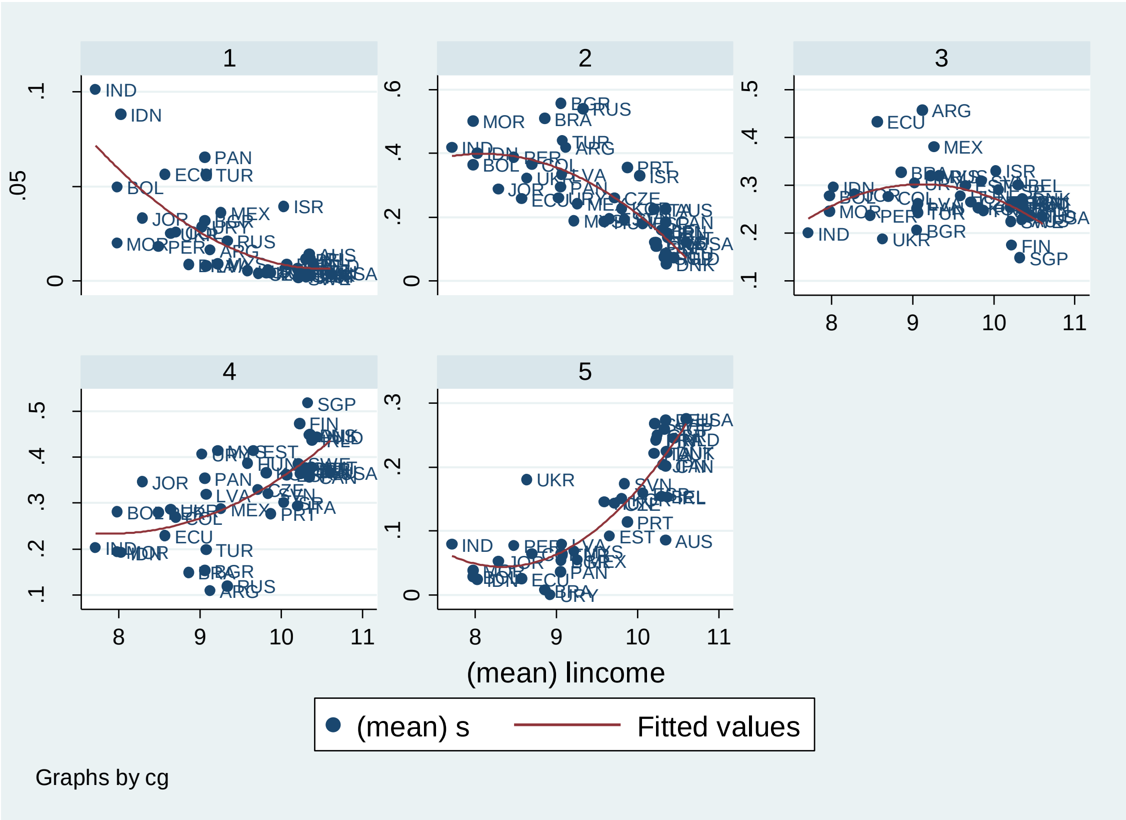
Cont. Table 7.6

Israel	4.34	7.24	3.96%	32.94%	33.01%	30.10%	0.00%	21	42	0.87
Argentina	3.96	7.20	1.62%	41.79%	45.69%	10.89%	0.00%	22	41	0.84
Russia	4.00	6.46	2.10%	53.96%	31.98%	11.96%	0.00%	27	41	0.90
Qatar	4.93	6.86	3.12%	53.97%	15.72%	27.15%	0.04%	16	41	0.46

Source: author's own elaboration (data from UNIDO)

Figure 7.5 illustrates the information in Table 7.6. There is a clear positive relationship between income level and concentration in high-complexity sectors and the contrary for low-complexity sectors.

Figure 7.5 - Patterns of specialisation and complexity by product complexity: 5 sectors



Notes: Vertical axis = labour employment share. Horizontal axis = lincome = log(income per capita). 1-5 labels indicate the level of complexity of the sector.
Source: author's own elaboration (data from UNIDO)

Moreover, the patterns in each category are distinct, being steeper in the extremes (1 and 5), which shows that both low-complexity and high-complexity sectors are dominated by countries in the opposite ends of the income scale. There is little participation of poor countries in 'rich sectors' and rich countries in 'poor sectors'. The two least complex sectors display a negative relationship with income and the two most complex a positive relationship. The intermediary-complexity sector (3) shows an expected quadratic pattern, indicating that countries increase their share in the process of development only to later reduce it.

The results in this section show a clear path of manufacturing development (inter-sectoral development traverse). Countries develop by progressively increasing their share of employment in high-complexity (high-sophistication) sectors. Ultimately, high-income countries are not those specialised in sophisticated products, but those with the most balanced distribution of employment across the whole range of products, being only relatively specialised in sophisticated products.

7.4. Structural sophistication and income levels

The relationship between patterns of specialisation and growth is a central tenet in the Structural literature, for which a number of studies estimate the impact of changes in level of diversification on growth and the association between patterns of specialisation and income levels (Hesse, 2008; Lederman and Maloney, 2007).

This section discusses the gains of including the ubiquity index in the assessment of the relationship between the productive structure and income levels. Equation (7.6) represents the reduced model to be estimated considering the existence of fixed-effects for individuals and time in a panel data model[193].

$$log\ (y_{i,t}) = \alpha + \beta_1 log(D_{i,t}) + \beta_2 log(U_{i,t}) + \gamma(X_{i,t}) + \delta(Z_{i,t}) + u_{it} \qquad (7.6)$$

Where y is the income level and D and U the diversity (kc2) and ubiquity (kp5) components of the complexity index, respectively. X is a k x 1 vector of possible endogenous explanatory variables, and Z is a vector k x 1 of independent control variables. The subscripts i and t refer to countries and year, respectively. The other elements are the traditional ones in panel data estimations: α is a constant, and u the residuals.

Control variables help preventing any bias in the parameters provoked by the channelization of the effect of omitted elements in y by D or U. The controls are from the Penn World Table 9.0 and include macroeconomic and institutional elements such as Investment levels, Inflation and Human

[193] The use of panel data has a few additional advantages. First, it allows testing for the importance of both the cross-sectional and time-series dimensions of the data. Secondly, it allows testing for the importance of sector-specific characteristics by estimating either a fixed or a random effects model (Cameron and Trivedi, 2005). See Appendix 3 for more details on the method.

Capital. Country and year dummies are also included amongst controls. This can help identifying the eventual differences in the impact of the complexity components on growth for these groups.

Table 7.7 presents the results of the estimation of equation (7.6). As expected, in all cases the diversification estimate shows a positive impact on income, while ubiquity was negative for most of them. An 1% increase in the number of sectors with RCA (kc0) increases the income by 0.1%-0.35%, while an increase of 1% in the number of countries producing the country's products (kp0) reduces the income by 0.1%.

Table 7.7 - Complexity and income-levels: cross-country (1990-2006)

Variables Log (per capita income)	Fixed-effects				IV regression - FE	
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Diversification of the productive structure - ln(kc0)	0.3579***	0.2106***	0.1473***	0.1009**	0.1116***	0.122**
	(0.0642)	(0.0636)	(0.0536)	(0.0426)	(0.0389)	(0.0587)
Average product ubiquity - ln(kp0)		-0.176***	-0.119***	0.075**	0.071***	-0.113***
		(0.0245)	(0.0211)	(0.0224)	(0.0204)	(0.0236)
Productivity level - ln(prod)			0.3076***	0.2556***	0.2244***	0.3629***
			(0.0246)	(0.0240)	(0.0222)	(0.0305)
Investment - ln(inv)				0.0318***	0.0269***	
				(0.0074)	(0.0067)	
Inflation - ln(dp)				0.2379***	0.1384***	
				(0.0182)	(0.0209)	
Human capital - ln(hc)					1.506***	
					(0.1923)	
Constant	8.362***	9.346***	4.473***	5.488***	4.066***	3.677***
	(0.2383)	(0.2619)	(0.4486)	(0.4628)	(0.4592)	(0.5466)
Observations	419	419	419	338	338	288
Number of countries (n)	45	45	45	38	38	38
R2 (within)	0.077	0.19	0.429	0.7045	0.7555	0.4926
F Adjusted (num. variables, n)	31.1	43.62	92.93	140.67	151.43	59100
Prob F	0	0	0	0	0	0

Notes: Standard deviations in parenthesis. Equation (vi): Instrumented: kc, kp, lprod; Instruments: L.income, lni, price_index, lnhc.
* 10% significance ** 5% significance *** 1% significance
Source: author's own elaboration (data from UNIDO)

The coefficients are relatively stable to different specifications. One case for consideration is the change of sign in the ubiquity variable in the more complete specifications. One hypothesis is that the controls introduced in the specification are correlated with the complexity component. This is expected, as productivity level and human capital are directly related to the productive structure of a country[194]. In order to check this hypothesis, specification (v) and (vi) estimate the model using the lag of the explanatory variables as instruments in a two-stage fixed-effects setup. The results are similar to the specification (iii) and (iv).

In conclusion, both diversity and ubiquity seem to determine the cross-country log-level of income, justifying the approach in this chapter. The exercise presents obvious advantages over previous studies that considered the impact of diversification alone (Hesse, 2008; Lederman and Maloney, 2007). Besides, since the effect of diversification and ubiquity are in the opposite direction, the inclusion of these variables separately, instead of the complexity indicator alone gives a better picture of the influence of each on the endogenous variable.

7.5. Concluding remarks

This chapter explored the relationship between capabilities, productive structure and growth. The first section briefly summarised the literature on industrial transformation. Section 7.2 recapitulated the Evolutionary perspective on the connections between capabilities and the sectoral composition in manufacturing. Following the approach of Felipe *et al*. (2011), both the product and country complexity indexes were discussed. The innovative application of the method of reflections to an industrial production database permitted identifying the necessary capabilities to produce different types of industrial goods. This was shown to corroborate the vast evidence based on international trade data in the literature. Using the industrial sophistication classification, a general pattern of development was proposed and empirically assessed. Finally an econometric exercise proved the importance of both diversity and ubiquity in the determination of income levels.

This chapter extended the works of Salter (1960), Rodrik and Hausmann (2007), Hausmann and Hidalgo (2009), Felipe *et al* (2011) in many aspects: from the use of a more actual database on the actual manufacturing production, instead of international trade, to its exclusive focus on the process of industrial transformation and the adoption of a refined index of the network of production and capabilities internalised by a country. The next chapter extends the Kaldorian model introduced in Chapter 2 to explain the patterns of specialisation here uncovered.

[194] Indeed, the most important element determining the log-level of income is the log-level of productivity, for which the coefficient ranged from 0.22 to 0.36.

8 Inter-sectoral development: a Kaldorian-Evolutionary approach

8.1. Introduction

This chapter concerns the adaptation of the Kaldorian growth model for the study of growth with heterogeneous agents. Revisiting the Kaldorian function of technological progress and hysteresis ideas, the chapter proposes a model where the endogenous process of structural change is the key for growth and dependent on both demand and supply requirements. The reconstitution of the supply side follows the Evolutionary principles developed in chapter 7.

The chapter is organised as follows. Section 8.2 discusses the integration of Evolutionary principles in the Kaldorian growth model. The section focuses on the key role played by income elasticities and Verdoorn's coefficient in the Kaldorian model, and shows how making these elements endogenous in the level of capabilities (complexities) internalised brings new possibilities to the analysis. The discussion evidences prior attempts to reconcile potential and actual growth rates in the Kaldorian tradition and the criticism on the appropriateness of it. Section 8.3 empirically explores the hypotheses in the conception of the model, discussing the relevance of such capabilities in the determination of both income elasticities and Verdoorn's coefficient. Section 8.4 concludes the chapter by showing that, in contrast with the intra-sectoral development process discussed in Chapters 5 and 6, the inter-sectoral development is, ultimately, a demand-led process.

8.2. Evolutionary foundations for the Kaldorian approach

As emphasised in Chapter 2, the explicit acknowledgment of the role played by the supply-side in the process of growth is perhaps the most important contribution of the Kaldorian approach to the demand-led growth theory. As envisaged by Kaldor (1970), growth involves the recursive interaction of demand and supply. This process creates an undisputable role for history in the model (cumulative causation). Nevertheless, in order to favour a framework of equilibrium analysis, the canonical Kaldorian growth model chose to rely on a 'weak path-dependence' mechanism: the initial conditions set by the structural parameters of the model: the income elasticity of demand and the Verdoorn coefficient (Setterfield, 1997).

> *"[the supply-side] is largely hidden from view, with a technological progress function (such as Verdoorn's law) providing the only explicit glimpse of the development of productive forces in the process of growth. This can give the resulting models an under-developed appearance, with supply-side accommodation of the demand-side occurring automatically but according*

> *to no explicitly- specified mechanisms of adjustment in a process that Cornwall (1972) likens to 'Say's law in reverse"* (Setterfield, 2013 p.22).

Implicit in such representation of the supply-side are the assumptions of free universal technology diffusion and homogeneous absorption (learning) capabilities, which go against empirical findings on the subject (Fagerberg, 1994, p. 1147). Besides, the undifferentiated nature of technological progress is equivalent to neglect any relevant role for the process of structural change in growth trajectories.

There is, however, much debate on the appropriateness of improving the supply-side representation in the Kaldorian model. According to McCombie (2011), the concern with reconciling 'actual' and 'potential' growth rates is '*at best misleading*', since, by assumption, the only important constraint binding in the Kaldorian growth model is imposed by demand. Thirlwall (2001) argues that, by definition, if the potential equals the actual growth rate there can be no such thing as a balance-of-payments constrained growth, while León-Ledesma and Thirlwall (2002) criticise the view of an exogenous natural rate of growth determined by supply conditions. With a sample of 15 developed countries over the post-war period, they showed that the labour force and productivity growth are elastic to demand and output growth, increasing in booms and falling in recessions. With the natural rate of growth endogenous, it would make little economic sense to think of supply constraints to growth. Nevertheless, the authors agree that demand can only create its own supply 'within certain limits' and that supply bottlenecks might cause inflation and balance-of-payments difficulties that may constrain demand and thus the process of growth.

Setterfield (2013) seems to agree with this caveat. According to the author, it is unlikely that demand-led growth will always be automatically accommodated by the supply side. He concludes for the importance of assessing the impact of supply constraints on growth, and the implications thereof for the steady-state in the demand-led model.

Attempts to reconciling actual and potential growth rates are not new in the Kaldorian literature. Kaldor (1959) himself advanced a model in which the actual rate of growth adjusts towards the Harrodian natural rate through changes in the functional distribution of income. Another seminal contribution is that of Cornwall (1972), who proposed a variety of mechanisms by which the supply-side can accommodate the development of the demand-side. Therefore, within bounds, the potential growth rate adjusts in equilibrium to the actual rate of growth.

More recently, Setterfield (1997, 2003, 2013) changed the model to include a mechanism 'strong path-dependence' so that *"the experience of a particular (equilibrium or disequilibrium) growth trajectory can induce discrete structural change associated with the economy's technology and/or institutions, as a result of which the economy will evolve through a series of discrete 'regimes' or 'episodes' of growth*" (Setterfield, 2003 p.216)[195].

Assuming strong path-dependence in the Kaldorian model is equivalent to proposing an endogenous Verdoorn coefficient. Accordingly, the economy becomes driven by a constant interaction between demand (the pushing force) and supply constraints (path-dependence). The structural change induced by the strong path-dependence mechanism, however, should not invalidate the notion of equilibrium if this is modelled as a traverse. The traverse analysis proposed by Setterfield (1997, 2003) assume the existence of gravity centres in the economy, defined by the path-dependence mechanism. In this, growth is characterised as a process of transition between two states. The analysis is straightforward and has the advantage of conserving the notion of equilibrium in a historical framework.

An alternative way to reconcile actual and potential growth rates in the first and second generation of Kaldorian growth models is by assuming hysteresis in the elasticities. Based on Kaldor's understanding of growth as a historical rather than an equilibrium process, McCombie and Roberts (2007) proposed a model where the income elasticities of demand [for exports + imports] are a nonlinear function of the past growth rate (enough to break with the features of the standard model of equilibrium). The ratio of the elasticities at a given point of time (t) can be written as follows:

$$(\varepsilon/\pi)_t = \gamma_1 + \gamma_2(\phi - \gamma_{t-1})\gamma_{t-1},\ \gamma_{1,2} > 0 \qquad \textit{(8.1)}$$

Where γ_1, γ_2 and ϕ are constants. According the authors, high rates of past growth have a negative impact on the income elasticities of demand. This occurs because the high-profitability fosters the phenomenon of lock-in in the productive structure, which should be constantly changing to meet the movement of world demand over time. Low rates of previous growth, in turn, generate a clamour for change and structural reforms, impacting positively the elasticities. In equation 8.1, the ratio of the elasticities is decreasing for lower values of the past growth rate, and increasing for

[195] The author argues that this is also one way to reconcile the Kaldorian approach on growth with Kaldor's original view on the non-equilibrium (historical) process of growth.

higher values of the growth rate of the previous income[196]. Although simple, this specification entails a strong message: the dependence of trajectory determines growth in the long-term.

In a different approach, Palley (2002) makes the income elasticity of the demand for imports a function of the excess capacity in the economy. This adds to the original system of equations a function of potential growth, which should be solved together with the effective growth. Accordingly, changes in capacity utilisation along the growth path induce short-term changes in the steady-state values of the BPCG model.

Beyond the labour and/or capital restrictions highlighted by the authors above, one important constraint binding on the supply side of modern economies concerns the different technological paths induced by different patterns of specialisation. According to the Evolutionary literature, technical change is the single most important force driving the secular process of growth (Metcalfe, 1988). As a way to verify the importance of technology lock-in associated with patterns of specialisation, Catela and Porcile (2010) propose that the ratio of income elasticities of demand for exports and imports is a function of the so-called 'Schumpeterian efficiency' (S) and 'Keynesian efficiency' (K). The latter captures the direct effects on the demand side from exports, and is represented by the share of exports represented by sectors in which the international demand grows faster than the world average. The concept of Schumpeterian efficiency (S), in turn, measures the ability of each country to dynamically accommodate changes in demand and technology, as well as sequentially change its production structure towards sectors in which demand grows faster. The model allows K and S interact in time so that they can endogenously produce different trajectories of growth and catching-up. In formal terms, Thirwall's law can be rewritten as:

$$y^* = \frac{(1+\eta+\psi)(p_d-p_f-e)}{\pi} + \frac{\alpha}{\pi}k + \frac{\beta}{\pi}s + \frac{\varphi}{\pi}z \qquad (8.2)$$

Where π, η and ψ represent the aggregate demand elasticities (see Chapter 2) and α, β and φ are the coefficients for the growth rates of K, S and Z, respectively[197].

[196] Assuming some values for the constants and substituting equation (8.1) in the original Thirlwall's Law (2.13), we obtain the growth rate of long-term compatible with equilibrium in BP, given the past growth rate.
[197] Empirical tests are significant and robust for both indicators, so that the authors conclude that the model contributes to help "opening the black box of elasticities" (Catela and Porcile, 2010).

A slightly different way to extend the responsiveness of Thirlwall's BPCG model to the process of structural change, without significantly altering its structure, is to assume that different sectors produce goods with different demand elasticities (determined by the product characteristics), as proposed by Araújo and Lima (2007). Accordingly, the productive structure becomes an important element for the determination of the country’s long-term growth as changes in the relative weight of sectors in the trade basket influence the country's aggregate elasticities. In formal terms, as demonstrated in Romero (2016), the BPCG equilibrium growth rate becomes:

$$y = \frac{\left(1+\sum_{i=1}^{k}\theta_i\psi_i+\sum_{i=1}^{k}\phi_i\eta_i\right)\left(p_d-p_f-e\right)+\left(\sum_{i=1}^{k}\phi_i\varepsilon_i\right)z}{\sum_{i=1}^{k}\theta_i\pi_i} \qquad (8.3)$$

Where the subscript i refers to the various sectors of the economy and ϕ_i and θ_i are the share of each sector in total exports and imports, respectively.

The next sub-sections propose a different mechanism to make the process of technological progress endogenous in both the first and second generation of Kaldorian growth models. The approach is based on the Evolutionary notion of capabilities and structural complexities. Both income elasticities and Verdoorn's coefficient are assumed endogenous in the level of capabilities accumulated by the economy[198]. Merging the contributions of these schools is not new in the literature. Since Cornwall (1972), a number of studies has been pursuing an improved representation of the supply side in the Kaldorian framework (Cornwall and Cornwall, 2002; Palley, 2002; Setterfield, 2003; 2013; Romero, 2015). In the Evolutionary literature, a growing branch of studies also addressed the feedbacks between demand and the process of technical change (Peneder, 2003; Castellacci, 2009; Dosi, Fagiolo and Roventini, 2010; Verspagen, 2002; Saviotti and Pyka, 2008).

8.2.1. The medium-term model revisited: endogenous technological progress function

The simplest way to account for the effect of different technological trajectories in the canonical Kaldorian model is to make Verdoorn's coefficient (λ) endogenous on the level of capabilities internalised by the economy. Assume, therefore, that λ is influenced by the cumulative process of development of the productive forces. This would give rise to a succession of contingent productivity regimes that are both cause and effect of productivity growth (Setterfield, 2003).

[198] The approach equals to the inclusion of an alternative "strong path-dependence" mechanism, as discussed above.

To see the possible effect of this change on the equilibrium output, assume that the level of economic complexity is a function of the set of capabilities ($\emptyset$) a country has internalised. The endogenous Verdoorn's coefficient (λ^*) can be thus written as:

$$\lambda^* = \emptyset\lambda \qquad (8.4)$$

Where $0 < \emptyset < 1$ represents the whole set of capabilities available worldwide. $\emptyset > 0$ means that every country has to internalise a minimum number of capabilities in order to produce any good. On the other hand, $\emptyset < 1$ reflects the fact that no country can actually internalise all the existing capabilities, since this would mean it has comparative advantages in the production of all goods[199].

Equation (8.4) states that technological progress responds directly to the level of capabilities internalised. $\emptyset$ gives the level of impairment to the full realisation of the technological progress due to the lack of necessary capabilities in the economy. Plugging λ^* in (2.4) and solving the system (2.4) to (2.7), the new equilibrium growth rate will be[200]:

$$y_E = \frac{\alpha[\omega_d d + \omega_x(\eta(w + \tau - \rho - p_f - e) + \varepsilon z)]}{1 - \alpha\emptyset\lambda\omega_x\eta} \qquad (8.5)$$

If all productivity gains are not passed on in the form of a slower rate of growth of prices, but in the growth of real wages and the rate of profit (through a growth of the mark-up τ), as is empirically plausible, this collapses to the simple rule.

In summary, the demand regime remains the same represented in Eq. (2.9): $y = \Omega + \alpha\omega_x\eta\rho$, while the productivity regime (Verdoorn's equation) now includes $\emptyset$, that is, $PR: q = \rho + \emptyset\lambda y$. The implications of this change are illustrated in Figure 8.1[201]. Countries with fewer capabilities would

[199] Setterfield (2003) illustrates the lock-in phenomena brought about by sectoral interrelatedness in a resembled approach.

[200] The model presented in Chapter 2 consists of the following set of equations:

(2.4) $q = \rho + \lambda y$

(2.5) $y = \alpha(\omega_d d + \omega_x x)$

(2.6) $x = \eta(p_d - p_f - e) + \varepsilon z$

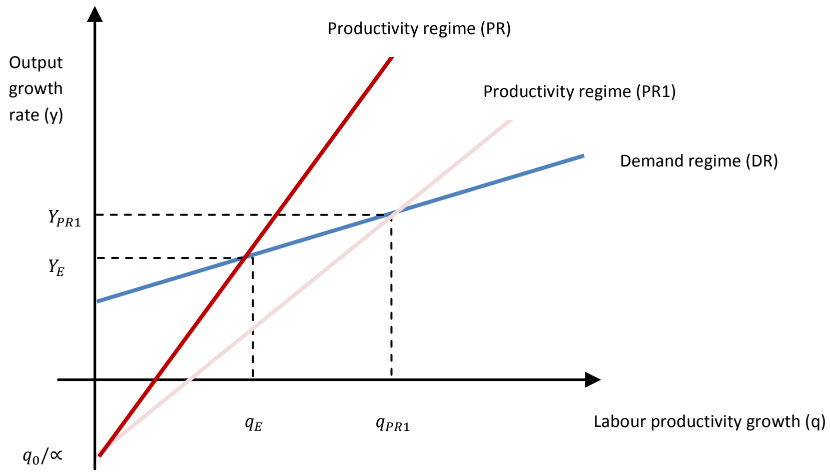
(2.7) $p_d = \tau + w - q$

[201] The demand regime results from the combination of equations (2.5) to (2.7), with $\Omega = \alpha[\omega_d d + \omega_x(\eta(w - p_f - e) + \varepsilon z)]$, while the productivity regime is represented by (2.4).

face a productive regime more steeped, compared to countries with a more complete capability set. In summary, if $\emptyset_1 > \emptyset_2$, then $\mathrm{Y}_1 > \mathrm{Y}_2$.

Considering the repetition of this process in time, one could also think that learning is a function of the level of capabilities internalised, and due to the fact it is an important determinant of the level of economic complexity, λ should also be raised by the process of growth. This would therefore enhance the dynamics of the cumulative process inherent to the model, but the productivity gain operates through the transformation of the productivity regime itself (change of PR) and not movements along PR.

Figure 8.1 - Demand and Supply equilibrium in the Kaldorian framework



Source: author's own elaboration

As discussed in Chapter 6, different sectors should present different technological regimes. The idea behind stipulating idiosyncratic sectoral regimes is a simple way to call attention to the importance of the productive structure and the lock-in phenomena in the process of development, also answering to the criticism on the sustainability of the equilibrium in the canonical Kaldorian model.

8.2.2. The long-term model revisited: endogenous elasticities

Since the mechanism of cumulative causation operates via prices, it has no influence on the long-term growth rate. The rationale behind it is that short- and medium-term spurts of (cumulative) demand-induced-growth slow down due to external constraints brought by the equilibrium conditions of the economy. Accordingly, the balance-of-payments equilibrium defines the equilibrium growth rate. The downside of the BPCG model is that it obliterates any influence of the technological progress on the growth rate of equilibrium, implying that, even though contrary to the empirical evidence, the inter-sectoral allocation has no influence on growth trajectories in the long-term. The only glimpse of the importance of the productive structure in the model is found in the exogenous income elasticity of demand, which sets the country's initial condition.

Should income elasticities respond to the level of technological progress dictated by the number of capabilities internalised by an economy, the BPCG model would immediately reconcile its results with the empirical evidence in the last chapter. To see this, assume that the demand for exports is given by equations (8.6) and (8.7):

$$x = \eta\left(p_d - p_f - e\right) + \varepsilon^{*} z \qquad (8.6)$$

$$\varepsilon^{*} = \varepsilon_0 + \varepsilon_1 \emptyset \qquad (8.7)$$

Where $0 < \emptyset < 1$ represents the share of the worldwide capabilities internalised by the economy and $\partial\varepsilon/\partial\phi > 0$. Differently from the original exogenous ε, the demand elasticity ε^{*} is a composite of the international income and product quality, i.e., the income elasticity of the demand (ε_0) and the quality elasticity of the demand (ε_1). The estimated values for ε^{*} hence differ with ϕ. Since income elasticities are intimately connected to the technological level of the production (Romero and McCombie, 2016-2), this hypothesis seems more sound than the original model's exogenous elasticity. The combination of (8.6) and (8.7) with (2.10) and (2.11), gives[202]:

$$y_{BP} = \frac{(1+\eta+\psi)\left(p_d - p_f - e\right) + \varepsilon^{*} z}{\pi} \qquad (8.8)$$

Equation (8.8) gives practically the same result as the seminal Thirlwall's law, with the exception of the conclusion that the income elasticity of demand for a country's export and, hence, the equilibrium growth rate is as high as the level of capabilities internalised.

More importantly, the positive effect of the cumulative process of structural change in the economy (which increases $\emptyset$) still holds in the hypothesis that relative prices have no impact in the long-term growth rate (i.e., in case either the elasticity pessimism and/or lack of variation in the rate of change of relative prices are valid). This offers a good counterpoint to Thirlwall's (1979) claim that the

---

202 (2.10) $m = \psi\left(p_f + e - p_d\right) + \pi y$
(2.11) $m + p_f + e = p_d + x$

cumulative causation mechanism can only affect the growth rate through relative prices, having thus no effect on the long-term growth rate of equilibrium. The new version of Thirlwall's law is given by:

$$y_{BP} = \frac{\varepsilon^* z}{\pi} \tag{8.9}$$

That is, the higher the ratio of the elasticities ε* and π, the higher the rate of growth compatible with the balance of payments equilibrium, as in the original model. However, the higher the level of capabilities internalised (i.e., structural sophistication of the economy), the higher ε*.

8.2.3. The Evolutionary-Kaldorian approach: making structural change endogenous on growth

Should both the Verdoorn coefficient and the income elasticity be endogenous in the level of economic complexity, as described in Sections 8.2.1 and 8.2.2, the resulting equilibrium would quickly reconcile the evidence in support of the Evolutionary theory with the Kaldorian approach. Solving the system of equations formed by (2.4), (2.7), (2.10), (2.11), (8.4) and (8.6)[203]:

$$y_E = \frac{(1+\eta+\psi)(w-p_f-e)-(1+\eta+\psi)(\rho)+\varepsilon^* z}{\pi+\emptyset\lambda(1+\eta+\psi)} \tag{8.10}$$

Allowing relative prices to change in the long-term growth gives rise to a combined effect of the structural elements in the equilibrium growth rate. If the elasticity pessimism holds, however, the balance of payments constrained growth rate will be given by Equation (8.9). In case relative prices are stable in the long term, only the first multiplicative parenthesis in the numerator is eliminated, resulting in an equilibrium growth rate highly dependent of the past history of growth, i.e., given by ε*, ρ and $\emptyset\lambda$.

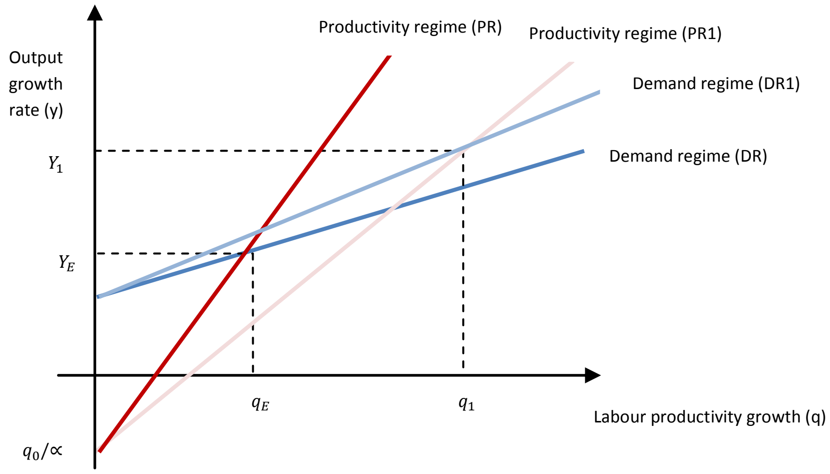
---

[203] Should the income elasticity be endogenous in the medium-term Kaldorian model (circular causation model), some new effect will also be available:

$$y_E = \frac{\lambda\left[\omega_d d + \omega_x\left(\eta\left(w - p_f - e\right) + \varepsilon z\right)\right] - \lambda\omega_x \eta q_0}{1 + \lambda\omega_x\eta\emptyset\alpha - \varepsilon}$$

As $\lambda\omega_x\eta\emptyset\alpha < 0$, the higher the $\emptyset\alpha$ (Verdoorn effect), the bigger the product multiplier. Besides, the structural change elasticity ε also fosters a bigger multiplier.

Figure 8.2 - Demand and Supply equilibrium in the Kaldorian framework



Source: author's own elaboration

The above model reiterates the self-reinforcing mechanism of interaction between demand and supply highlighted in Kaldor's original scheme, which was left out in the long-term Kaldorian model. The accumulation of capabilities in the process of growth should reflect both in the productivity regime ($PR: q = \rho + \emptyset\lambda y$) and demand regime ($DR: y = \Omega + \alpha\omega_x\eta\rho$), since both depend on $\emptyset$. This is illustrated in Figure 8.2, where an increase in $\emptyset$ moves PR to PR1 and DR to DR1, because $\Omega = \alpha[\omega_d d + \omega_x(\eta(w - p_f - e) + \varepsilon^* z)]$. In other words, the sophistication of the economic structure makes the inclination of DR steeper at the same time that it makes PR flatter ($y = (q - \rho)/\emptyset\lambda$), increasing the equilibrium growth rate that is now q_1 instead of q_e.

Yet there are many ways to improve this model. For example, one could consider $p_d = w + \tau - \rho = 0$. That is, assume that the growth of productivity depends on the growth rate of real wage and the rate of change of the mark-up (i.e., increasing profits). With profits related to capabilities then it will affect the value of ε. Also, one could consider that the income elasticities of imports are influenced by the country's rate of technological progress. The structural change towards a more complex system of production would thus reduce the growth of the demand for imports due to an increase in the income level. Consequently, the equilibrium growth rate should increase.

8.3. Empirical investigation: the sectoral demand and supply requirements

The empirical validity of the Kaldorian model is vastly documented in the literature (cf. McCombie and Thirlwall, 1994; Thirlwall, 2011). The discussion in the previous section adds new dimensions to the theory, making the model closer to Kaldor's seminal proposal and to the Evolutionary view.

This section aims at providing empirical validation for the augmented model of Section 8.2. The analysis follows the same strategy adopted in the investigation of the foundations of the intra-sectoral development trajectory and estimates the Kaldorian structural parameters for different sectors, here differentiated by the level of sophistication (complexity). From the discussion above, a country is as rich as the level of capabilities it has internalised. Such capabilities are reflected at both the level of increasing returns to scale and income elasticities of demand, what would impact both its regimes, PR and DR. It is argued that such an approach can also cast light on the foundations of the Kaldorian model.

8.3.1. Data

The data is provided by the third version of the UNIDO Industrial Statistics Database (INDSTAT). The sample comprises annual information for 125 industrial sectors of 46 countries in the period 1991-2009. The database preparation and sample selection are presented in Appendix 1.

8.3.2. Sectoral demand elasticities

The increasing evidence in favour of the connection between income elasticities of demand and the technological content of the output (Felipe *et al.*, 2011; Romero and McCombie, 2016-2) led some authors to conclude that the development of the economic structure contributes to relaxing the balance-of-payments constraints to growth (Gouvêa and Lima, 2010; Romero, Silveira and Jayme Jr., 2011). Although associated with the sectoral composition, such elasticities are determined by demand and consumption patterns, what would make of the inter-sectoral trajectory of development a demand-led process.

To investigate this hypothesis, this section estimates the income elasticities across different classes of product complexity. Consider the following demand function for each complexity group j:

$$Q_j = P^{E_p} Y^{E_y} \qquad (8.11)$$

where P are prices, Y the income, E_Y is the income elasticity of demand, E_p the price elasticity of demand, and Q the demand for the good of the complexity group. Taking logarithms from both sides and adding controls:

$$ln\,(Q)_{it} = \beta_0 + \beta_1 ln\,(P)_{it} + \beta_2 ln\,(Y)_{ct} + \beta_3 X_{it} + u_{it} \qquad (8.12)$$

where the subscript i represents 'country-sectors', c the country and t is the year. X_{it} is a group of control variables which include sectoral, country and five-year dummies, and u is the error term. Equation (8.12) was estimated by panel data methods, with each 4-digit ISIC sector at a specific country being a unique sector. The multinational country-sector panel considerably increases the number of observations available, improving the efficiency and consistency of the regressions.

Table 8.1 reports the results for the estimation of equation (8.12) for each of the four complexity categories discussed in the last chapter[204] by Blundell and Bond's (2000) 'System GMM' approach with fixed-effects and an FE-IV model. The first enables both the inclusion of the lagged endogenous variable in the specification – to capture convergence effects – and the use of lagged exogenous variables as instruments, reducing the correlation in the data. The fixed-effects free the estimation from country-sector specific effects. Appendix 3 provides further detail on the methods.

Table 8.1 - Demand function by complexity categories: panel data estimation, country-sector (1991-2009)

Variable	Low complexity		Medium-Low		Medium-High		High complexity	
	FE-GMM	IV-FE	FE-GMM	IV-FE	FE-GMM	IV-FE	FE-GMM	IV-FE
Log (output)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)
log(Y)	0.489***	0.533***	0.868***	0.915***	1.232***	1.271***	1.655***	1.714***
	0.1176	0.1289	0.099	0.1102	0.0889	0.1012	0.1336	0.1478
log(P)	-0.848***	-0.830***	-0.705***	-0.610***	-0.56***	-0.41***	-0.47***	-0.133
	0.0542	0.069	0.051	0.073	0.0546	0.0794	0.0743	0.1339
Constant	19.370***	18.838***	14.461***	13.503***	10.33***	9.268***	5.238***	3.036
	1.2135	1.3088	1.0376	1.1453	0.9653	1.1257	1.4091	1.5848
N	9428	9428	13529	13529	16975	16975	9130	9130
F	160.6863	64.8295	190.3583	76.8322	225.84	117.0212	124.4349	76.3578
Prob > F	0	0	0	0	0	0	0	0

Notes: *p<0.1, **p<0.05, ***p<0.01. Dummies and controls omitted.
Source: Author's own elaboration (data from UNIDO)

The coefficients are highly significant and stable at different specifications, indicating good adjustment of the data. This is confirmed by the highly significant F test. The column (i) in each group uses lags of the explanatory as instruments, whereas columns (ii) the lagged income and logarithms of human capital and population as instruments[205].

[204] Low complexity comprises the 20% lowest complex sectors, high complexity the 20% of sectors with the highest complexity, and the intermediary categories around 30% each.
[205] Both are from the Penn World table 9.0.

The comparison across complexity groups reveals a clear positive relationship between the sectoral level of sophistication and the income elasticity. An increase of 1% of the income would result in an increment of around 0.5% in the demand of low complexity sectors, but of 1.65-1.71% of high-complexity sectors products. The value of the parameters reflect a form of Engel's law, where the basic goods of low-complexity sectors are inelastic to income ($\beta_2 < 1$) and the sophisticated products from higher-complexity sectors highly elastic.

Table 8.2 reports the results for the estimation by fixed-effects of the demand function with multiplicative dummies for the sectoral income elasticities. Both the multiplicative β_2's of Equation (8.12), and the standard deviation are illustrated. The results are close to the ones found in the previous estimations and confirm the positive relationship with the level of complexity of the production. Wald tests confirm the differences in the coefficients across complexity groups at the 1% significance level.

Table 8.2 - Demand function by complexity categories (1991-2009)

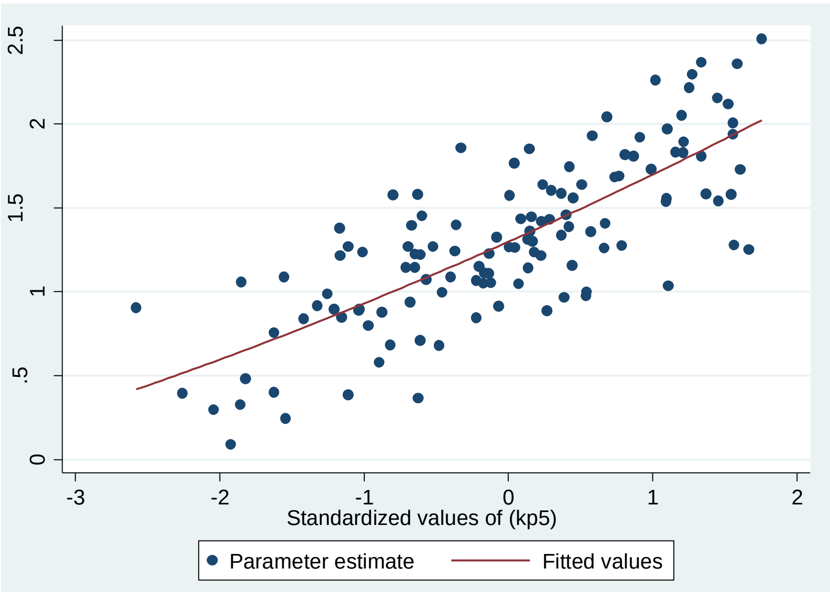
Variable	β_2
Low complexity	0.3993***
	0.0347
Medium-low complexity	0.8766***
	0.029
Medium-high complexity	1.226***
	0.0255
High complexity	1.727***
	0.0353
Log(P)	-0.708***
	0.0061
Constant	12.676***
	0.1702
N	49062
R2	0.4006
F(5,44462)	5943.52

Notes: Dependent variable: log(output)
*p<0.1, **p<0.05, ***p<0.01.
Source: Author's own elaboration (data from UNIDO)

The results are consistent with the overall story of development put forward in this study. The influence of demand on the development trajectory seems much stronger at the inter-sectoral level than at the intra-sectoral level (see Chapter 6). For the former, the relationship between the demand requirements and product sophistication is linear (it increases circa 0.4 by each superior complexity class), revealing an important potential of influencing the income. At the intra-sectoral level, demand fosters the de-concentration of sectors by stimulating smaller firms (income elasticity is bigger than the unit) in comparison to larger businesses, for which the demand elasticity is inferior to the unit. This was shown to be contradictory with the trajectory of intra-sectoral development, which follows the path of technological progress and favours large business.

Figure 8.3 depicts the relationship between the sectoral income elasticity and the sectoral sophistication index (kp5) for all 4 digit ISIC sectors in the database. The income elasticity increases with the sectoral level of complexity. The red line illustrates the positive and linear relationship between the elements. The correlation between the two variables is of 77.51. The coefficient of inclination is 1.582 (statistically significant at 1%) and the R^2 of the regression of the elasticities in kpp is 0.6. These results corroborate Felipe *et al.*'s (2011) findings when estimating the same relationship for 5107 export products.

Figure 8.3 – Sectoral Income elasticities and product complexity: world economy, ISIC4 sectors



Notes: Each point is a ISIC 4-digit manufacturing sector. Vertical axis: sectoral income elasticity of demand; Horizontal axis: standardised values of KP5.
Source: author's own elaboration (data from UNIDO)

8.3.3. Sectoral-specific productivity regimes

The productivity regime (PR) curve in section 8.2 was represented by the Kaldorian function of technological progress. This section investigates if the coefficient of Verdoorn varies across sectors, justifying the hypothesis of sectoral-specific technological regimes.

In fact, although there is now an extensive literature on Verdoorn's Law, only few studies were dedicated to the investigation of the law at a sectoral level. Among them, McCombie and de Ridder

(1983) estimated the returns to scale of four sectors: manufacturing, mining, agriculture and services, confirming the existence of increasing returns only in the first. McCombie (1985) investigated the law at the 2-digit manufacturing disaggregation for the US. Angeriz, McCombie and Roberts (2009) estimated the law for 6 sectors across European regions, Tharnpanich and McCombie (2014) for sectors in Thailand. Within manufacturing the evidence is yet rarer. Only recently, Romero (2015) investigated whether supply-side characteristics of goods from different manufacturing sectors influence the degree of returns to scale. He concluded that these are higher for high-tech sectors, compared to low-tech ones, which can be explained by the characteristics of the demand for high-tech products.

Table 8.3 presents the results of the estimation of Equation (6.10) across complexity groups $i = \{low, \ldots, high\}$ instead of firm size classes[206]. That is:

$$tfp_{it} = \beta_0 + \beta_1 y_{it} + \beta_2 G_{it} + u_{it} \tag{8.13}$$

The technological groups are classified by their level of sophistication as in the previous section. Only one estimation is reported: the SYS-GMM with lags for all explicative variables, even though the lags are omitted in the table as they were not significant at the 5% level. Different sectoral desegregations, such as adopting 3 and 5 complexity sectors, lead to the same pattern below. For comparison, Romero and McCombie (2016-1) discuss only two technological sectors.

From the results below, one may conclude that high-complexity manufacturing sectors present higher returns to scale than low-complexity manufacturing industries. It is interesting to note that the magnitude of the estimated elasticities of productivity growth in relation to output growth are similar to the coefficients in Romero and McCombie (2016-1), also ranging from 0.5 to 0.9. The higher level of disaggregation in this work shows though that the relationship between returns to scale and product sophistication is non-linear. The coefficient increases from low to medium-low-complexity industries, where it peaks. Medium-high-complexity sectors already face lower returns to scale compared to the latter, and the parameter for high-complexity sectors approximates to the value estimated for the low-complexity group. T-tests confirm that these are different at 5% level of significance.

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[206] See chapter 2 and 6 for a discussion on the different specifications and estimation of Verdoorn's law.

Table 8.3 - Dynamic demand-side Kaldor-Verdoorn's Law by complexity group: panel data estimation (1990-2006)

Sectors/Variables	Low	Medium-Low	Medium-High	High
tfp	(i)	(ii)	(iii)	(iv)
y	0.5866***	0.8807***	0.8089***	0.6693***
	0.1288	0.0719	0.0372	0.0535
Constant	4.624*	-1.5913	-0.038	2.894**
	2.645	1.6564	0.8128	1.171
N	825	2491	2083	543
F	10.36	74.86	235.76	78.08
Prob > F	0	0	0	0
Sargan	733.27	3345.63	348.21	286.4
Prob > chi2	0	0	0	0
Hansen	0.5	0.7	-0.98	0.41
Prob > Z	0.615	0.487	0.327	0.678

Notes: Gap and Year dummies omitted. *p<0.1, **p<0.05, ***p<0.01
Source: Author's own elaboration (data from UNIDO)

Robustness tests corroborate the results in all the estimations. The Sargan test reported for SYS-GMM estimations rejected the null hypothesis of over-indentified restrictions, validating the choice of instruments by groups. Also, the Arellano and Bond AR test for autocorrelation did not reject the null hypothesis of no autocorrelation in any of the regressions at the 5% significance level, while Hansen's J test did not reject the null hypothesis of the validity of the instruments at the 5% significance level.

The results above indicate that the supply dynamics is especially important at the early stages of the inter-sectoral development process, but not as much in mature stages. Again, this corroborates the hypothesis that the inter-sectoral development process, which is directed to more complex sectors, is a demand-led process (driven by income elasticities). The structural change towards higher-complexity sectors will occur even in face of lower technological opportunities in these sectors, as demonstrated by the lower Verdoorn's coefficient for high-complexity sectors.

Since different sectors present different income elasticities of demand (Tables 8.1 and 8.2) and different technological progress functions (Table 8.3), one might expect that both DR and PR curves vary with the country's sectoral composition. The higher the level of structural sophistication, the higher the demand regime curve. As for the productivity regime, the curve's inclination is steeper at intermediate levels of product sophistication and flatter otherwise, meaning that countries at intermediate levels of development should encounter higher technological opportunities compared to poor and rich countries.

8.4. Concluding remarks

This chapter concerned the adaptation of the Kaldorian growth framework for the study of growth with heterogeneous sectors and the investigation of its hypotheses. This was possible by a reconsideration of the supply-side's role in the model. Aided by ideas from the Evolutionary approach, it proposed a reinterpretation of the structural elements in the first- and second-generation growth models. It was shown that a simple re-specification of the mechanism of path-dependence enables such sectoral divergences and brings new significance for the process of structural change in the income trajectory.

The adoption of Evolutionary concepts to improve the supply-side representation in the Kaldorian framework is certainly a promising field, especially for the large complementarities that exist between the approaches. The model introduced presents several advantages over the canonical Kaldorian model:

(i) It provides a more balanced account of the importance of both demand and supply elements for the process of growth, doing justice to Kaldor's original ideas.
(ii) It contributes to clarifying the nature and characteristics of the (underdeveloped) Kaldorian function of technological progress and its cumulative effects in the productive structure.
(iii) It permits the influence of patterns of specialisation and structural change on growth.
(iv) It helps reconciling the cumulative causation mechanism with the balance-of-payments log-term equilibrium (without assuming price changes).

The final section of the Chapter investigated the empirical validity of the hypotheses of the extended model. Demand elasticities and the Kaldorian technological progress function were estimated in different specifications using robust methods across complexity sectors. The results show both: (i) a linear relationship between income elasticities and the level of sophistication of the sectoral product, confirming previous studies that adopted technological aggregations in the estimation of sectoral elasticities; and (ii) an inverted-U relationship between the sectoral complexity and the Verdoorn coefficient. These led to the conclusion that, contrary to the intra-sectoral development trajectory, the inter-sectoral trajectory is a demand-led process, which corroborates the Kaldorian emphasis on the effect of demand on income levels.

The next chapter explores the interactions between these two different and concomitant phenomena, the [supply-led] intra-sectoral trajectory and the [demand-led] inter-sectoral trajectory of development, and how these might explain worldwide divergences in both patterns of specialisation and market-structures.

9 Demand and supply requirements for growth: a Kaldorian-Evolutionary approach

9.1. Introduction

The multilevel evidence in the previous chapters revealed an important stylised fact of the process of industrial development: while increasing returns associated with the concentration of the market-structure give the push to the intra-sectoral development process, the demand trajectory orients the level of sophistication of the productive structure, furnishing the incentives for the inter-sectoral development. This entails two important conclusions: (i) both demand and supply play a key part in growth trajectories; (ii) each fulfils a different role in the general process of development, which is only apparent from a multi-level analysis.

Given that these are concomitant and inter-dependent processes occurring at different analytical levels, a fundamental question is how demand and supply interact in the development trajectory. Do they reinforce each other or create contradictory forces in the development traverse?

This Chapter investigates the interplay between demand and supply in the overall development trajectory. The next section contrasts the empirical evidence at both intra- and inter-sectoral levels. The results suggest that the supply-led phenomenon at the intra-sectoral level creates dynamic forces that foster both the intra- and inter-sectoral development. By its side, the demand-led phenomenon at the inter-sectoral level forges marginally contradictory forces, which pushes growth at the inter-sectoral level, but, at the same time, constrains the intra-sectoral development process. One can say that the supply dynamics creates bottom-up (from firms to sectors) incentives for economic growth, whereas the demand dynamics creates top-down (from sectors to firms) constraints to growth.

In light of these results, Section 9.3 introduces a transformation model based on Cornwall and Cornwall (1994, 2002). Such model enables both the representation and interplay of demand and supply in the same framework. The approach ratifies last chapter's highlighted complementarities between Kaldorian, Structural and Evolutionary studies. The development traverse is finally illustrated in a 3-sector representation. The final section concludes the chapter.

This Chapter makes several contributions to the literature. Firstly, the interplay between the intra-sectoral and the inter-sectoral dynamics has not been explored in the allocation literature, for which each analytical level constitutes a separate line of research. In addition, the analysis shows that the interaction between demand and supply requisites in each of these 'layers' of the development process can explain important stylised facts of the growth process. These include the quadratic evolution of the firm size in the sectoral development traverse, demonstrated in Chapter 6, and divergent patterns of specialisation and growth trajectories worldwide. Furthermore, it shows how the insights of the Evolutionary literature can be treated within the multi-sectoral Kaldorian framework. A final contribution is in showing how the intra-sectoral dynamics (the foundations of the growth process) can be represented in a macro model without resorting on non-analytical multilevel approaches.

9.2. The interplay between demand and supply in the growth process: empirical investigation

Chapters 6 and 7 presented each a different perspective of the process of economic development. The firm size (sectoral level of concentration of the market-structure) is the protagonist of the intra-sectoral-development story, whereas the technological regime shapes the trajectory. That is, given the sectoral boundaries, the supply-side development asks for an ever greater level of concentration of the market-structure. At the inter-sectoral analytical level, the process of economic development has a different drive, the demand, which pushes the economy to ever higher levels of structural sophistication (complexity).

The phenomena above are not independent. In fact, the empirical analysis showed that intra-sectoral trajectories might diverge from the predicted – logistic – path determined by the technology due to counteracting effects of the demand on the market-structure[207]. As discussed, the growth of income (demand) seems to promote the de-concentration at higher levels of development, reducing thus the rhythm of innovation at the sectoral level. At the same time, the evidence of a quadratic (inverted-U) relationship between returns to scale and product sophistication indicates that supply constraints might explain divergent patterns of specialisation and non-convergent growth trajectories.

[207] The availability of labour also seems to create constrains to full realisation of the technology.

Contrasting the evidence on these two different analytical levels, this section seeks to understand the interplay between demand and supply in the overall process of development. Using data from the intra-sectoral database (SDBS)[208], Table 9.1 depicts the average values of labour productivity, investment and output and employment shares by firm size class and sectoral complexity group.

Table 9.1 - Selected variables by structural sophistication group and size: world economy, average (1991-2007)

Sectors	SCL	Labour Productivity[1]		Structural composition[2]		Investment[3]	
		Ratio	Δ*	Labour	Output	Ratio	R&D
High	NSC-1	0.104	3.7%	9.3%	4.2%	3.4%	0.4%
	NSC-2-3	0.134	2.0%	22.0%	12.8%	2.5%	0.3%
	NSC-4	0.195	2.7%	24.9%	21.1%	3.1%	0.8%
	NSC-5	0.325	3.3%	43.8%	61.9%	3.2%	2.6%
	Average	**0.189**	**3.0%**	**25.0%**	**25.0%**	**3.0%**	**1.0%**
	GAP**	**0.221**	**-0.4%**	**34.6%**	**57.6%**	**-0.2%**	**2.2%**
Intermediate	NSC-1	0.09	2.8%	13.4%	6.0%	2.5%	0.1%
	NSC-2-3	0.145	3.1%	26.3%	18.6%	2.1%	0.1%
	NSC-4	0.211	3.1%	26.0%	26.9%	2.7%	0.4%
	NSC-5	0.29	2.5%	34.3%	48.4%	2.6%	1.5%
	Average	**0.184**	**2.9%**	**25.0%**	**25.0%**	**2.5%**	**0.5%**
	GAP**	**0.199**	**-0.4%**	**20.9%**	**42.4%**	**0.1%**	**1.4%**
Low	NSC-1	0.063	4.1%	18.7%	14.7%	2.0%	0.1%
	NSC-2-3	0.076	6.9%	32.0%	27.9%	1.6%	0.0%
	NSC-4	0.084	5.5%	30.2%	29.2%	1.8%	0.1%
	NSC-5	0.132	12.1%	23.9%	34.7%	1.7%	0.1%
	Average	**0.089**	**7.2%**	**26.2%**	**26.6%**	**1.8%**	**0.1%**
	GAP**	**0.069**	**8.0%**	**5.2%**	**20.0%**	**-0.3%**	**0.0%**

Notes: Data on NSC-2 and NSC-3 are merged at size class NSC-2-3 for ease of showing. * Growth rate. ** NSC-5 productivity value minus NSC-1 productivity value. 1 Output/Employment ratio. 2 Share in total employment and output. 3 Investment/Output ratio.
Source: author's own elaboration (Data from the SDBS)

The table reveals a series of important patterns, possibly responsible for internal and external gaps (heterogeneities). Firstly, both the average productivity and intra-sectoral gap (the difference between the productivity values for NSC-5 and NSC-1 firms) increase with the level of sophistication of the product (cross-sector analysis), confirming that technological opportunities are higher at more sophisticated sectors. This is corroborated by the average investment and R&D expenditures, both of which increase with product sophistication index. The latter also indicates that high-complexity

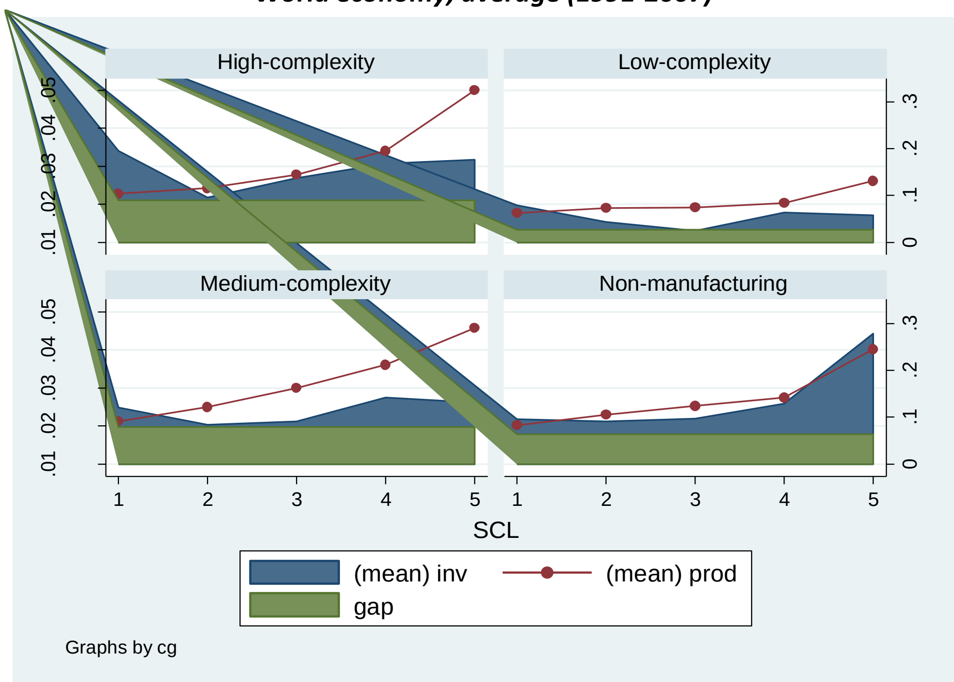
[208] The intra-sectoral database comprises annual data between 1991-2009 on 5 size classes for 35 countries organised by the 2-digit ISIC sectors. For details on the database preparation and sample selection see Appendix 2.

sectors probably have a greater influence in the economy's overall productivity level, since spillovers are directly associated with the level of R&D.

The comparison between output and employment shares gives an important clue on the level of returns to scale at each complexity group. In each sector, the employment share is bigger than the output share for all firm size classes, except for NSC-5 firms. Such advantages of large firms corroborate the fourth Chapter's finding that the important variable at the intra-sectoral level is not the distribution of firm sizes – as the misallocation literature proposes – but the share of large business in the sectoral market-structure. Moreover, the R&D and investment rates increase with the level of sectoral sophistication, again indicating that new levels of technological opportunities are opened as a country moves up in the sophistication scale.

Figure 9.1 reinforces the conclusion that large firms are particularly important in high-complexity sectors (observe the steepness of the cross-size productivity curve in this group). The productivity increases monotonically with firm size for the sector of intermediate-complexity. The productivity of the low-complexity sector presents the smallest dependence on the firm size. This sector is also the one with lowest levels of investment and R&D, an indication of the low levels of technological opportunities (illustrated by the small internal gap).

Figure 9.1 - Investment, Productivity and Gap by SCL and product sophistication: World economy, average (1991-2007)



Notes: Gap = difference in the productivity indicator between NSC-5 and NSC-1 firms. Horizontal axis = firm size classes; Left vertical axis = inv = investment/output ratio; Right vertical axis = labour productivity rate.
Source: author's own elaboration (data from the SDBS)

It is argued that contrasting the information on the sectoral market-structure with the country level of structural sophistication reveals important characteristics of the actual sectoral trajectory of development that neither sectoral productivity levels nor income levels can do. Indeed, the cross-country evidence in Chapters 3 and 4 shows that it may be counterproductive to look at the trajectory of labour productivity as the element explaining the sectoral development path, since the highest levels of sectoral productivity are found for countries of intermediate development level. At the same time, as shown in Chapter 7, since the dynamics of each sector (and countries' specialisation patterns) diverge greatly (see Figure 9.1), the product sophistication index is more informative on the level of industrial development than income levels. The country level of product sophistication provides thus a much more accurate measure of industrial development than income levels and sectoral productivity levels, as it captures the country's competitive advantages in the production of manufactures.

Figure 9.2 plots the data on the sectoral level of concentration against the country complexity index for each of the ISIC-2 sectors. This illustrates the trajectories of development of these sectors and the role of the concentration of the market-structure in the process[209]. Two distinct phases of the traverse are revealed and separated by the vertical line[210]: (i) at the left side of the red line, the level of concentration is increasing with the sophistication of the productive structure (kc), peaking at around the value of 0.5 of the index; (ii) a de-concentration pattern is noticed from this point on, as the productive structure of the country moves from a medium to a high level of sophistication. It is important to note the significant sectoral differences in both the sectoral level of concentration (y axis) and the steepness of the curve.

Some key conclusions are reached:

(i) the process of inter-sectoral development seems to affect the intra-sectoral development trajectory, replacing the initial positive relationship between concentration and development by a contrary pattern. This explains why most empirical studies find no conclusive evidence in favour of the influence of firm size in growth, even though they

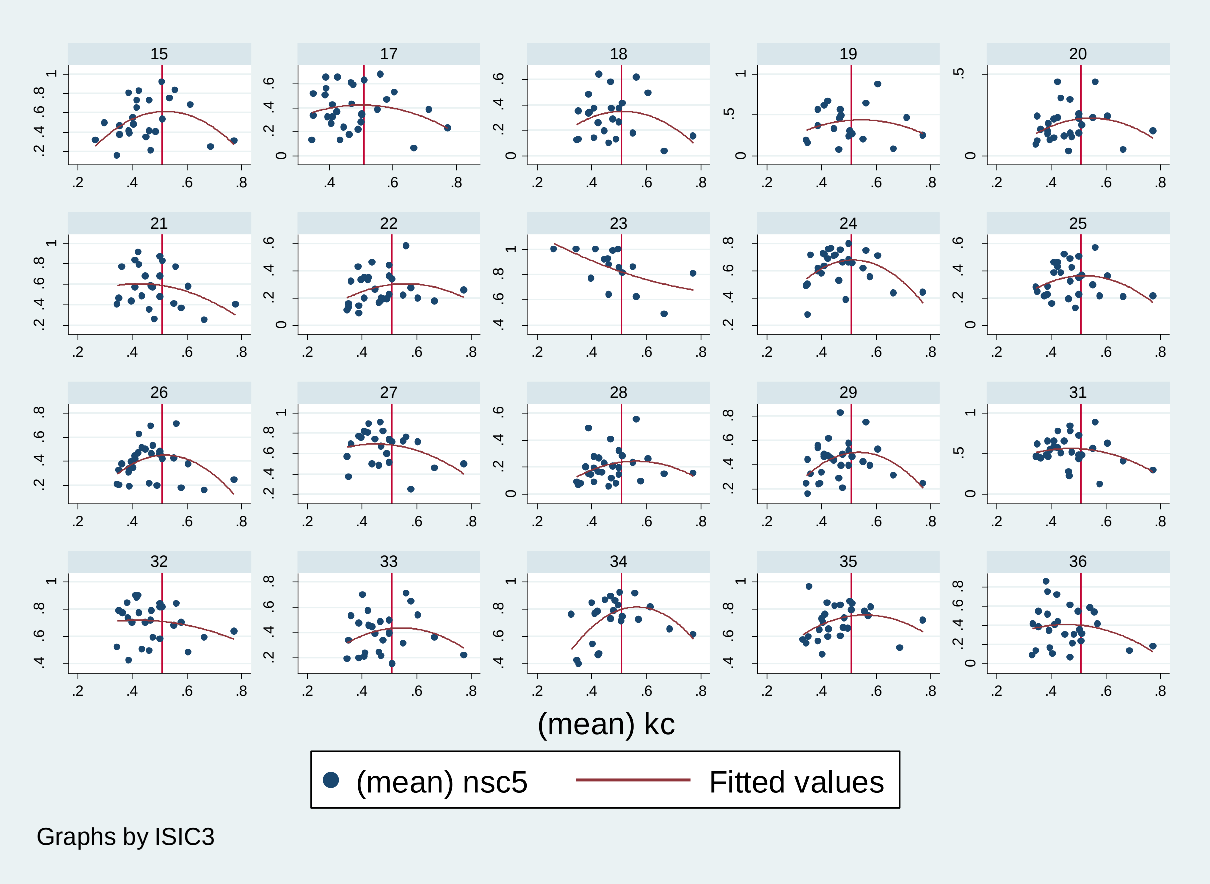
[209] If the complexity index is replaced by income per capita the patterns are not so clear and present a much higher variance across sectors, which illustrates the appropriateness of country sectoral complexity index in the measurement of the of sectoral trajectories of development.

[210] The vertical line in the Figure is at the exact point 0.5091 of the kc index, where 75% of the less sophisticated countries in the sample are on the left and the 25% more sophisticated on the right.

acknowledge the existence of large heterogeneities and a clear positive relationship between firm size and productivity measures (Cohen, 1995).

(ii) As evidenced by the results above, the process of growth seems to be triggered initially by the returns to scale associated with firm size. The development of supply (concentration of the market-structure) increases the level of income fostering the development of demand (i.e., the structural sophistication), which, in turn, will lead to the de-consolidation of the market-structure and relative specialisation in more sophisticated sectors.

Figure 9.2 - Sectoral participation of large business (NSC-5) and country complexity: world economy, selected ISIC-2 sectors, average (1990-2006)



Notes: Horizontal axis = country complexity index (kc); Vertical axis = labour share of NSC-5 in total employment
Source: author's own elaboration (Data from the SDBS)

What is the key switch in this process? What is behind both the change in the intra- and inter-sectoral patterns? The evidence in Chapters 6 and 8 corroborate the hypothesis that demand constraints act at the intra-sectoral level limiting and ultimately reverting the consolidation process at the cost of the full realisation of the technology of individual sectors. Supply requirements, by its side, act on 'liberating' the exploration of new levels of complexity and structural sophistication, which opens higher technological opportunities in new sectors, even though this process is non-monotonic and decreases as the country becomes developed (See Chapter 8). This may also affect positively the established sectors via labour reallocation and/or spillovers.

In summary, the comparison between the intra- and inter-sectoral development trajectories explains why some countries diversify their production, whereas other get locked-in to specific specialisation patterns, as well as why the sectoral market-structure diverge worldwide. The answer is in the level of incentives and impairments that both demand and supply impose on the multi-level development trajectory. That is to say, (i) how much the development of supply translates into income increases that enable the process of industrial complexification[211]; and (ii) how much the development of demand contributes to reduce the level of concentration of the market-structure and, hence, the dynamicity of the process of technical change. It should be noted that both effects are probably associated with the country's distribution of income as evidenced previous chapters.

The next section proposes a macro growth model that incorporates the dynamics of both supply and demand in a framework of Kaldorian and Evolutionary inspiration.

9.3. Industrial transformation: a Kaldorian-Evolutionary approach

In the story of development developed in this dissertation, growth is not a unidimensional process, but a complex phenomenon that requires structural variation and the interplay between demand and supply at distinct analytical levels. The foundations of this process are to be found in the heterogeneity of the basic units, firms and sectors, and their path-dependent development trajectories.

Modelling growth as an endogenous and multilevel process with heterogeneous agents is, however, a huge challenge. The Evolutionary literature has been 'wrestling' with this level of complexity since its seminal works (c.f. Nelson and Winter, 1982). Numerical simulations, where different hypothetical scenarios are explored, are abundant in the literature. More recent works in the tradition have adopted a number of different strategies, which range from limiting the level of variability in the environment, to incorporating meso-foundations to reduce the level of complexity. It is common in the recent literature the use of agent-based models, which lack an analytical response, but acknowledge the complexity of the process of growth. Less complex models, such as

[211] And how much it represents a disincentive as the country becomes developed (inverted U pattern).

the multi-sectoral analysis of Hausmann and Hidalgo (2011) and Lucas (1993), also require the calibration of a large set of parameters. This is also the case for Pasinetti's (1981) multi-sectoral approach, which depends on input-output relationships.

Based on the evidence summarised in the last section, this section presents a simple model in the Kaldorian tradition that connects the trajectory of growth with the process of structural change. It requires little calibration. The structural heterogeneity is sourced in sectoral differences in demand elasticities and trajectories of productivity increase (returns to scale). Section 9.3.2 includes the Evolutionary elements discussed Chapter 7 in the model and assesses the impact of the process of structural change in manufacturing in the context of three sectors classified by the level of product sophistication.

9.3.1. The Kaldorian transformation model

Originally proposed by Sundrum (1990), the following framework was adapted by Cornwall and Cornwall (1994, 2002) to describe the secular process of industrialisation in capitalist economies. The multi-sector model connects the trajectory of growth with the process of structural change through using the Kaldorian parameters. The structural heterogeneity, represented by differences in both demand elasticities for the sectoral product and distinct trajectories of productivity (returns to scale), are the forces behind the transformation process. Among the main advantages of this framework is the fact that both demand (via income elasticities) and supply (via the sectoral productivity growth rates) influence the economy-wide productivity and growth rates. The versatility of the model enables the analysis of different scenarios with little adaptation of the structure.

To see it, assume that the average growth rate of labour productivity of an economy ($\dot{q}$) is given by:

$$\dot{q} = \frac{q' - q}{q} = \sum \frac{\lambda'_i q'_i - \lambda_i q_i}{q} \tag{9.1}$$

Where the prime indicates the end of period values, $q = \sum \lambda_i q_i$ is the average productivity of the economy, q_i = average sectoral labour productivity in the i_{th} sector, λ_i represents the sectoral share of labour force employed ($\sum \lambda_i = 1$), and $\dot{q}_i$ the sectoral productivity growth. If $k_i = \frac{\lambda_i q_i}{q}$ represents the sectoral output share, using the definitions of λ_i and k_i in (9.1) yields:

$$\dot{q} = \sum k_i \dot{q}_i + \sum \frac{(\lambda'_i - \lambda_i) q'_i}{q} \tag{9.2}$$

That is, the average growth rate of productivity is a function of two elements: (i) the weighted average sectoral productivity growth rates; and (ii) the labour reallocation between sectors with different productivity levels. The possible effect of a reallocation of labour, therefore, is also product of these two elements: (a) changes in the output share resulting from input shifts from one sector to another, making the level of productivity growth to converge towards the rate presented by the sector absorbing labour; (b) if productivity levels diverge between sectors, the reallocation of labour induces an increase in the average productivity growth rate. These relationships are formally presented in equation (9.3), which uses the definition of output or income elasticity of demand (ε_i). The latter is defined as the rate of growth of output of sector i as the total output grows, that is, the growth of output of sector i as the income grows[212], $\varepsilon_i = f(y) = \frac{\lambda'_i q'_i - \lambda_i q_i}{\lambda_i q_i \dot{q}}$:

$$\lambda'_i - \lambda_i = \frac{\lambda_i(\varepsilon_i \dot{q} - \dot{q}_i)}{1+\dot{q}_i} \qquad (9.3)$$

Equation (9.3) describes the movement of labour in and out the i_{th} sector as a function of both its income elasticity and its productivity growth rate. At the prevailing sectoral distribution of the labour, the sectoral growth rate of per capita output equals the sectoral productivity growth rate. If the growth of demand exceeds the growth of productivity, labour shifts into that sector. Since $\sum(\lambda'_i - \lambda_i) = 0$, the right-hand side of Eq. (9.3) yields an expression for the average productivity growth rate in terms of the economy sectoral composition:

$$\dot{q} = \frac{\sum \frac{\lambda_i \dot{q}_i}{1+\dot{q}_i}}{\sum \frac{\lambda_i \varepsilon_i}{1+\dot{q}_i}} \qquad (9.4)$$

That is, ultimately, the sectoral composition of the economy and the supply and demand dynamics, through the sectoral productivity growth rate and sectoral income elasticities, respectively, determine the economy's productivity growth rate.

9.3.2. A three-sector example

The development traverse described in Section 9.2 and supported by the evidence in the previous chapters can be easily represented in this framework. For that, consider an economy with three

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[212] See Cornwall and Cornwall (2002 p.227).

sectors, defined by the level of complexity (low-intermediate-high). These represent the three different stages of the logistic growth path emphasised in Chapter 6: (i) the basic stage, at lower levels of income, where low-complexity industrial sectors (food, beverages, textiles, wearing and apparel, and resource-based commodities) account for most of the industrial output and employment; (ii) the intermediate stage, where the productive structure is less specialised and reaches labour intensive and highly dynamic sectors of intermediate complexity; and (iii) the mature stage, when the income level is already high and, by effect of demand, labour moves to capital intensive and high-complexity sectors.

For each of these stages, an average level of productivity growth can be attributed, representing the point at the logistic function of technological progress the economy finds itself. The productivity growth rate reaches its highest level at the intermediate stage, whereas the lowest growth rates are found at the basic stage.

The specification of elasticity functions and the assumption of constant sectoral growth rates of productivity are sufficient to ensure that, as income rises, the ratio of elasticity and productivity growth of the low-complexity sector will fall in comparison with that of the intermediate-complexity sector, so that labour shifts into the latter, increasing the economy-wide productivity.

From Eq. (9.3), the employment share in the low complexity sector will change as follows:

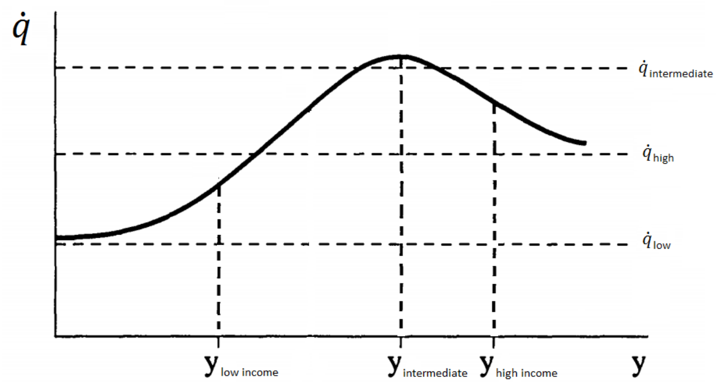
$$\lambda'_l - \lambda_l = \frac{\frac{\lambda_l \dot{q}_l}{1+\dot{q}_l}\left[\frac{\lambda_m \dot{q}_m}{1+\dot{q}_m}\left(\frac{\varepsilon_l}{\dot{q}_l} - \frac{\varepsilon_m}{\dot{q}_m}\right) + \frac{\lambda_h \dot{q}_h}{1+\dot{q}_h}\left(\frac{\varepsilon_l}{\dot{q}_l} - \frac{\varepsilon_h}{\dot{q}_h}\right)\right]}{\frac{\lambda_l \varepsilon_l}{1+\dot{q}_l} + \frac{\lambda_m \varepsilon_m}{1+\dot{q}_m} + \frac{\lambda_h \varepsilon_h}{1+\dot{q}_h}} \qquad (9.5)$$

where the subscript l represents the low-complexity sector, m the intermediate-complexity and h the high-complexity sector. Clearly, labour shifts into sector i if $\frac{\varepsilon_i}{\dot{q}_i} > \frac{\varepsilon_l}{\dot{q}_l}$. That is, labour moves from sectors of lower income elasticity in relation to their productivity growth into those with higher ratios. The aggregate productivity growth rate converges to the sector that is absorbing labour, i.e. the sector with the highest $\frac{\varepsilon_i}{\dot{q}_i}$ ratio.

As income continues to rise, the demand elasticity/productivity growth ratio of the high-complexity sector rises, while the ratios of the other two sectors continue to fall. Eventually, high-complexity sectors start absorbing labour and the economy-wide productivity growth converges towards this sector's rate.

This is illustrated in Figure 9.3, which depicts the relationship between the average productivity growth rate ($\dot{q}$) and the per capita income level (y). At a low income level (y_{low}), $\dot{q}$ approximates to the average growth rate of low-complexity sectors ($\dot{q}_{low}$). As income rises, the demand for mid-complexity sectors rises more than proportionally, attracting labour to these sectors and increasing $\dot{q}$, which peaks at the level of income the economy is more concentrated in the intermediate-complexity sector ($y_{intermediate}$). The latter is the most dynamic sector, presenting a high average growth rate ($\dot{q}_{intermediate}$). At higher levels of income (y_{high}), demand for high-complexity sectors rises and labour flows to this sector, reducing the growth rate to $\dot{q}_{high}$.

Figure 9.3 - The industrial transformation process



Source: Adapted from Cornwall and Cornwall (1994)

At any time, the average rate of growth of labour productivity in the 3-sector economy is given by Eq. (9.6):

$$\dot{q} = \frac{\frac{\lambda_l \dot{q}_l}{1+\dot{q}_l} + \frac{\lambda_m \dot{q}_m}{1+\dot{q}_m} + \frac{\lambda_h \dot{q}_h}{1+\dot{q}_h}}{\frac{\lambda_l \varepsilon_l}{1+\dot{q}_l} + \frac{\lambda_m \varepsilon_m}{1+\dot{q}_m} + \frac{\lambda_h \varepsilon_h}{1+\dot{q}_h}} \qquad (9.6)$$

That is, the overall economy's growth rate will depend on the relative participation of each of these sectors in the country's output and their dynamicity.

9.3.3. Empirical fit

The development traverse depicted in Figure 9.3 depends on two important hypotheses[213]: (i) the sectoral elasticities of demand are higher the higher is the level of complexity of the sector; (ii) the dynamicity of the growth process depends on the country's level of specialisation in each sector. The relationship between the level of structural sophistication and the rate of technical change is logistic.

Table 9.2 presents the estimated income elasticities and Verdoorn coefficients[214] for three complexity sectors of the World Economy. The Verdoorn coefficient, as the element representing the supply side dynamics, gives the sectoral rate of productivity growth (potential). The actual growth rates in each sector could also be used to illustrate the supply dynamics since it presents the same pattern across sectors: a logistic/quadratic relationship with the sectoral complexity, peaking at the intermediate complexity sector. The income elasticity represents the dynamics of demand and increases with the level sectoral complexity.

Table 9.2 - Demand and Supply dynamics

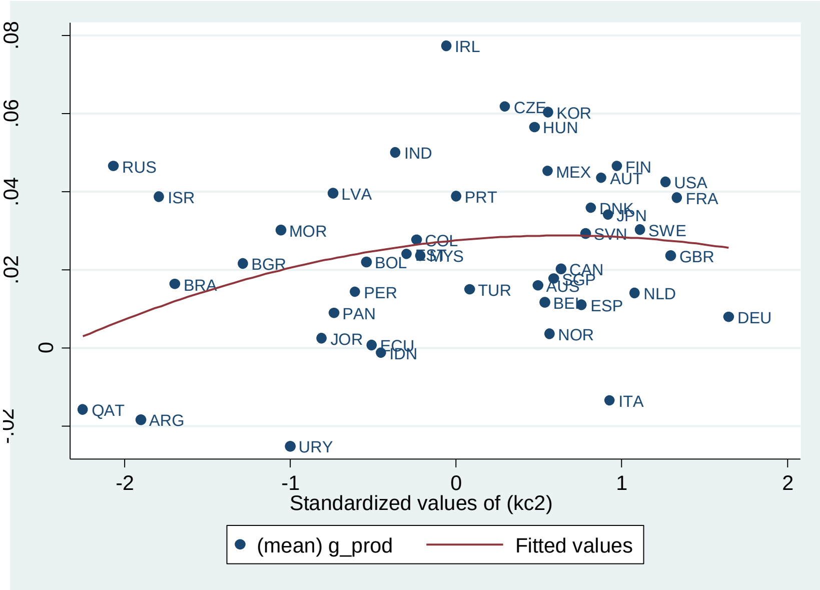
	Sector		
Estimate	Low	Intermediate	High
Income elasticities (ε_i)	0.489	1.083	1.655
Verdoorn ($\dot{q}_i$)	0.587	0.861	0.669
ε_i / $\dot{q}_i$	0.833	1.258	2.474

Notes: see Chapter 8 for the estimations and sample.
* average coefficient for medium-low and medium-high sectors.
Source: Author's own elaboration (data from UNIDO)

This indicates that the representation in section 9.3.2 is accurate. This is confirmed by the ratio $\varepsilon_i \,/\dot{q}_i$, which grows with the level of sectoral complexity, indicating that labour will indeed shift from low complexity to higher complexity sectors in the development traverse. Figure 9.4 replicates Figure 9.3 and plots the average productivity growth rate by the level of manufacturing development (complexity) for the 45 countries in the inter-sectoral database.

[213] Strictly speaking, another hypothesis is necessary: the growth rates of population and labour force are assumed constant, so that productivity and per capita income grow at the same rate.
[214] The results in Table 9.2 are based on a 3-sector estimation using the same model and specifications of Chapter 8. The data is from the inter-sectoral database (UNIDO) introduced in Chapter 3. This comprises information on 125 sectors of 45 countries in the period between 1991-2008. The database preparation and sample selection are further discussed in the Appendix 1.

Figure 9.4 - Average manufacturing productivity growth rate and country complexity: average (1991-2007)



Source: author's own elaboration (data from UNIDO)

The red (fitted values) line evidences the expected quadratic pattern for the relationship. The growth rate accelerates as the country productive structure becomes more complex and ultimately reduces as the manufacturing sector is already developed. The adjustment is not perfect though and the coefficient only significant at 10% level of confidence. This can be explained both by limitations of the database, but also by the effect of economic policies, which can distort such trajectories. The next section discusses this possibility.

The process of structural change is illustrated in Figure 9.5. This plots the country's log-level of per capita income by the employment share in each sector. The figure shows a clear positive relationship between income and concentration in high complexity sectors. More importantly, the inclination of the curves (fitted values) indicates that growth and structural change occur in an ordered but non-linear pace. That is, as income grows, a poor country quickly sheds labour away from low-complexity sectors[215]. This is incorporated in the intermediate-complexity sector, while the relative employment of the high-complexity sector remains constant. Only at higher levels of income, labour moves from intermediate-complexity sectors to high-complexity sectors. This process accelerates as income increases.

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[215] Since no poor countries are represented in the sample, the participation of low complexity in the economic structure is low compared to the other sectors (see the vertical axis).

Figure 9.5 - Patterns of specialization and complexity by product complexity: 3 sectors, average (1991-2009)

Note: Horizontal axis: lincome = log(rgdp); Vertical axis: total labour employment share.
Source: author's own elaboration (data from UNIDO)

In summary, the above representation seems to confirm the hypothesis that the process of manufacturing transformation involves the internalisation of context-specific and path-dependent capabilities in a proximate fixed order. Each sector presents a specific function of technological progress and higher levels of growth can only be achieved by increasing the level of sophistication of the productive structure. At the same time, the higher purchasing power brought by the inflated technological progress is not translated into a proportional increase of demand for different goods and services, due to Engel's law[216]. The economy becomes more diversified, but also relatively specialised in high-complexity sectors, the higher the level of income. The development of supply boosts growth at initial stages of development, inducing the development of intermediate-complexity sectors, and the development of demand reduces the pace of technical change, with the incentive to high-complexity sectors that, for being capital intensive, free labour to move to lower

[216] In this vein, Engel's Law constitutes one of the mechanisms blocking the prompt diffusion and absorption of international knowledge in developing countries. In summary, the investment-specific nature of technological progress in the 'New Economy', added to the balance of payments constraints and to the deterioration in the terms of trade, make the diffusion and absorption of new technologies in the South a daunting task (Araújo, 2011).

complexity sectors. One special characteristic of the high-complexity sector, however, is that it possibly creates important externalities for the other sectors of the economy[217].

9.3.4. Economic policies and development trajectories

The multilevel analysis in the previous chapters distinguishes between two concomitant and interdependent development trajectories, each of which is dominated by either demand or supply conditions, but affected by both. Even though the transformation model just discussed focuses on the inter-sectoral development traverse, the intra-sectoral dynamics is evidenced in the trajectory of supply. This fixes each stage's growth rate, being central to the transformation process.

One important question still open is how exogenous changes in supply and demand affect the development traverse. Figure 9.4 does indeed shows a diversity of trajectories, which might be explained by policies and country-specific constraints.

Consider an once-over change in the level of per capita income, a demand policy – which is equivalent to a change in the income elasticities caused by either monetary or fiscal policies that alters consumption patterns, for instance. Treated for convenience as an instantaneous change, this causes a movement along the curve in Figure 9.3 and horizontal shifts (from curve I to II) in Figures 9.6(a) and (b), which show the time path of productivity growth[218], and the logarithm of per capita income levels against time, respectively. Therefore, if, for instance, at time t_2 the level of income rises from y_b to y_c, the economy-wide productivity growth rate ($\dot{q}$) will grow from B to C'. There is a caveat though: the outcome of demand policies will depend on the country's level of complexity. If the demand boost occurs in t_3, for example, the speed of the growth process actually reduces (from C to D').

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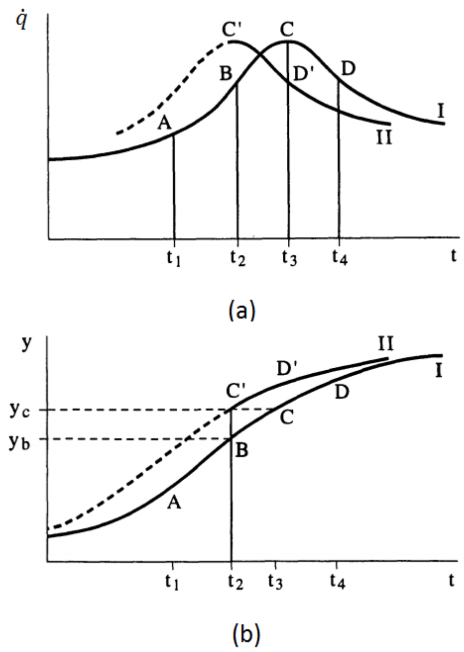
[217] As the complexity of the environment increases, it is expected that externalities start to spillover from dynamic/transversal industries (as is the case of electronics) to other industries (Fagerberg and Verspagen, 1999). Fagerberg (2000) highlights the benefits accruing to countries that increase the relative participation of technologically most progressive industries in their productive structure.

[218] The shape of the curve shows that it takes longer to move from A to B than from B to C, although the income increase is the same in each case.

Figure 9.6 - Demand policies and the growth traverse

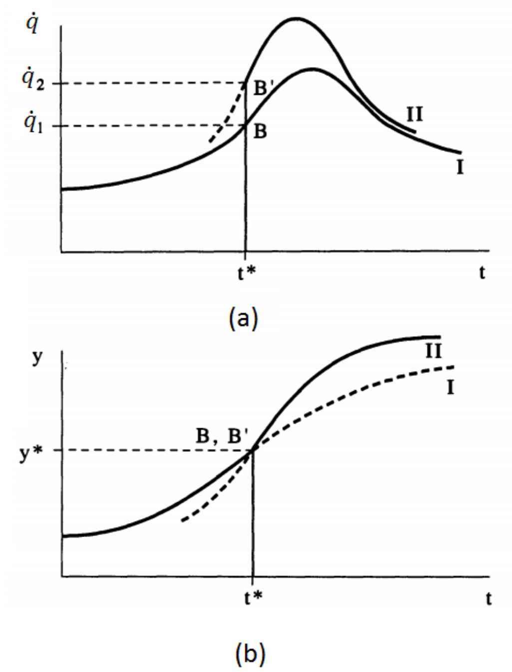


Source: Adapted from Cornwall and Cornwall (1994:242)

Consider now an once-over shock in the supply, as a technology transfer (catch-up), which effected in an increased productivity growth in one or more sectors at time t*, when the per capita income level is y*. This causes the logistic curve to shift upward, from I to II in Figure 9.7(a). $\dot{q}$ is now higher at each level of income, so that the logistic is traversed faster. Again, this shift speeds up the process of structural complexification if it happens at lower levels of income, but it also hastens the advent of a productive specialisation that lowers the productivity dynamicity (structural lock-in).

In summary, demand policies can induce horizontal changes in the traverse, whereas supply policies provoke vertical ones. The outcome resemble though. In both cases a higher level of income is achieved, however, because this shortens the transformation process, they both induce the structural lock-in, leading the economy to a slower long-term equilibrium rate. The demand policy can even have a negative effect on the growth rate of productivity, depending on the level of structural complexity of economy. In both cases, the results will depend on the level of constraints to the development of the productive structure. Cornwall and Cornwall (2002) discusses the impact of different elements in the common growth path. According to the authors, success in exports can delay the rapid growth phase[219], whereas an extended high unemployment may flattens the productivity growth trajectory, reducing the potential productivity of factors in the economy.

Figure 9.7 - Supply policies and the growth traverse



Source: Adapted from Cornwall and Cornwall (1994:244)

The analysis of the effect of economic policies can be significantly improved by knowing (i) the strict connection between supply trajectories and firm size in sectoral regimes, and (ii) the importance of income level and patterns of consumption in the shape the sectoral composition of an economy. The evidence in this dissertation, therefore, can contribute to the formulation of specific policies oriented to either fasten and/or prolong the dynamic phase of growth.

As showed, the effectiveness of economic policies depends of a fine combination of shocks in demand and supply at each level of development. A redistributive policy that expands the consumption at lower levels of development could reduce the potential development of sectors[220], which is yet far from their maximum productivity level, and stimulate the demand for products that the economy cannot produce in competitive terms (due to the low level of capabilities internalised), increasing the dependency on imports. Equally, a policy oriented to the development of specific

[219] This might be the case, for the increased demand allows higher levels of concentration in the sectoral market-structure.
[220] For it increases the demand of less productive small businesses.

chains of production and sectors, which might promote the full utilisation of the benefits of scale economies, only makes sense at lower levels of development. A demand policy would have better results at intermediate levels of development.

9.4. Concluding remarks

Profiting from the results of the previous chapters, this chapter explored the multilevel interplay between demand and supply in growth trajectories. The analysis showed that the intra-sectoral development process, which requires the concentration of the market-structure, fosters the development of the productive forces of the economy, increasing income levels. At the inter-sectoral level, the rise of income encourages the opening of technological opportunities with new (more sophisticated) sectors, at the same time that it fosters the de-concentration of the market-structure, reducing the intra-sectoral process of technical change. Different results are possible, from the lock-in to a complete diversification of the productive structure. The key to growth is in the strength of the supply and demand incentives and constraints in the inter-sectoral and intra-sectoral development processes, respectively, which will probably depend on the distribution of income and institutional characteristics of the country.

Finally, a 3-sector model of Kaldorian inspiration exemplified the development traverse and the effect of economic policies. The approach showed that the multi-level development trajectory described in the previous chapters can be represented in a one-level-multi-sectoral framework, provided that the dynamics of both demand and supply are sufficiently detailed. Such an approach is much simpler and still accurate when compared with complex, multilevel and agent-based analyses typically found in the Evolutionary literature[221]. The results are consistent with the cross-country process of industrial development, revealing the importance of structural sophistication and the interaction between demand and supply for growth. Moreover, the analysis detailed the effects of demand and supply policies on the traverse, discussing their appropriateness at each stage of development. The political implications of the approach are further explored in the next chapter, which concludes this dissertation.

[221] Even though the intra-sectoral dynamics can be proxied by the sophistication of the economic structure in the more broad analysis, a number of policy implications are only revealed by the consideration of the intra-sectoral dynamics in the analysis.

10. Summary, conclusions and policy implications

This dissertation introduced a fresh view of the role of resource allocation in determining growth trajectories. More than simply investigating the pervasiveness of structural heterogeneities and the influence of structural composition on growth, it pursued the causes of structural differentiation and proposed a unified theoretical framework to connect the multi-level evidence. In the story of development built in the nine chapters of this thesis, growth is not a unidimensional process, but a complex phenomenon that requires structural variation and the interplay of demand and supply requisites in distinct analytical levels.

Two particular layers of this process were emphasised: the intra-sectoral development trajectory and the inter-sectoral development trajectory. The dynamics of first layer depends on the intensity of the process of technical change. The key element is the firm size or, more specifically, the sectoral level of concentration, which was shown to perform a major role in promoting innovation and productivity growth at the sectoral level. This is depicted as a supply-led phenomenon, where returns to scale are increasing with firm size. The dynamics of the second layer is associated with the structural complexification of the economy, which is guided by demand. This was shown to be a cumulative process, which requires the acquisition of capabilities in an orderly way.

The key to economic growth is to be found in the interaction between these layers. As discussed, the supply-led process of sectoral development creates the conditions for the inter-sectoral development, which in turn affects the intra-sectoral evolution. At the inter-sectoral level, the development of demand promotes both the increment of the structural sophistication (diversification and relative specialisation in high-tech sectors) and the sectoral de-consolidation of the output, for the income elasticities of demand increases with the sophistication of the product and decreases with firm size, respectively. The first process opens new technological opportunities, since the sophistication of the structure seems to influence the technological trajectories of all sectors, whereas the second constrains the intra-sectoral development by stimulating the reduction of the level of market concentration. The final development trajectory will depend thus on the interaction between supply and demand requisites, which is probably influenced by the distribution of income and a number of political and institutional elements specific to the country.

The ten chapters of this dissertation are separated in four sections. Section I reviewed the theoretical foundations of the allocation problem and specific gaps in the literature. The first chapter introduced the main concepts of the analysis and discussed the Evolutionary explanation for economic heterogeneities. The review encompassed the more recent branches of meso-level-Evolutionary studies, which emphasise the interdependence of market-structure and innovation at one level and the bonds between product sophistication and the productive structure at the other level. After a critical summary of the empirical research, the limitations of the approach for the study of the multi-level allocation problem were discussed. The second chapter introduced the Kaldorian contribution to growth theory, emphasising the versatility of the framework and the representation of demand and supply in the models: the income elasticities and the Verdoorn coefficient. These were later shown to be key instruments in the analysis of Sections III and IV.

Section II investigated the empirical relevance of the multi-level allocation problem and the pervasiveness of economic heterogeneities. A symmetrical approach for the inter-sectoral (Chapter 3) and the intra-sectoral (Chapter 4) analytical levels was adopted, giving comparability to the results. A number of empirical patterns and stylised facts emerged and oriented the approach in Section III, where each of these layers were studied in detail. Chapter 3 showed that the sectoral breakdown influences the results of growth accounting and shift-share exercises. Econometric exercises confirmed the relevance of inter-sectoral allocation problem for growth. The contribution of Chapter 4 lies in its original perspective of the allocation problem, but also in the exercises, which, to date, have never been used in intra-sectoral studies. The results corroborate the neoclassical misallocation findings, with the advantage of not relying on the restrictive hypotheses of the latter.

Section III focused both on (i) overcoming the limitations of the theoretical literature to explain the multi-level allocation problem; and (ii) investigating the empirical validity of the multi-level development trajectories and their determinants. The first layer is presented in Chapter 5, which introduced a model of sectoral development based on Nelson and Winter (1982). Both the micro-foundations of the process of technical change as well as the sectoral development traverse were discussed. On the empirical side, the chapter presented evidence of the validity of the hypotheses, which yet needed to be reconciled with the notion of technological regimes, the object of the next chapter.

Chapter 6 proposed a general technological progress function and discussed how the evolution of firm size and market concentration create divergent trajectories in the same technological regime.

The analysis showed that to think of firm size as a key element in the process of sectoral development is not antithetical with the notion of technological regimes. The divergence between the actual and predicted patterns of intra-sectoral evolution was explained by effect of the demand – represented by the income level and associated with the productive sophistication of the economy. The seminal estimation of Verdoorn's coefficient and income elasticities across firm size categories confirmed the hypothesis.

Chapter 7 investigated the validity of Evolutionary inter-sectoral development model, which associates the productive structure with specific capabilities. The connection between capabilities and the sectoral composition was formally established by the combination of Evolutionary and Structural elements. Following the approach in Felipe *et al*. (2011), both the product and country complexity indexes were discussed. The innovative application of the method of reflections to an industrial production database permitted identifying both the necessary capabilities to produce different types of industrial goods and international trajectories of industrial development. Lastly an econometric exercise investigated the connections between economic complexity and income levels, highlighting the relative advantage of the notion over diversification indexes usually adopted in sectoral studies.

Chapter 8 concerned the adaptation of the Kaldorian model for the study of the process of inter-sectoral development with heterogeneous agents. The undifferentiated technological progress in the model was shown to limit the growth representation. The Evolutionary school lent the ideas for the requalification of the supply side in the canonical model. The approach reinforced the complementarities between the Evolutionary and Kaldorian theories explored by recent works in both streams. The approach was corroborated by the estimation of both Verdoorn's law and income elasticities of demand for each of the categories of product sophistication (complexity). Two conclusions emerged from the analysis: (i) the inter-sectoral development trajectory is led by the demand, and (ii) the supply dynamics has a contradictory effect on the sectoral specialisation, favouring intermediate-sophistication sectors rather than either low or high sophistication sectors.

The final section of this dissertation combined the results of the previous chapters in a policy-friendly framework. Chapter 9 assessed the interplay between demand and supply trajectories and proposed an Evolutionary-Kaldorian transformation model that synthesises the influence of these elements in growth trajectories. The joint analysis of the intra- and inter-sectoral development trajectories revealed that the development of demand offsets some of the gains brought by the concentration, whereas the final impact of the development of supply depend on how the productivity gains are translated into income and consumption. The multi-sectoral model showed that the multi-level development trajectory described in the previous chapters can be represented in a one-level framework. The results were consistent with the cross-country process of industrial development, revealing the importance of structural sophistication and the interaction of demand and supply for growth.

Among the contributions that this dissertation makes, one may highlight: (i) the innovative multi-level perspective of the allocation problem, for the first time studied altogether; (ii) the unprecedented study of the foundations of the allocation problem; (iii) the original application of static and dynamic methods to measure the pervasiveness of the multi-level structural heterogeneity and the impact of structural change on growth; (iv) the original perspective of the development problem, treated as a multi-level and complex phenomenon; (v) the unprecedented association between demand and supply requirements with each of these specific layers of the process of development; (vi) the original integration of Schumpeterian, Kaldorian and Structuralist ideas for the study of the sectoral dynamics and its influence on long term growth.

Moreover, the approach addresses important limitations in both the Kaldorian and Evolutionary literatures, namely:

a. The lack of foundations of the Kaldorian growth model (King, 2010: 166). Demand elasticities were shown to vary across firms and sectors, favouring smaller firms and sophisticated sectors. The cause of the phenomenon still needs further investigation, however, qualifying the demand requisites in the canonical Kaldorian model certainly contributes to improve the applicability of policy implications deriving from the model. The discussion on returns to scale and the representation of the supply-side in the Kaldorian literature is more complicated. Understood as a macro phenomenon, only recently the determinants of increasing returns to scale in manufacturing became object of investigation. Britto (2003) estimated the law by hierarchical models to show that its impact can be identified at the firm level. Romero (2015) showed that high-tech industries present higher returns to scale than low-tech industries and that the difference in the magnitude of the scale economies between the two groups increased in the last decades. No other study, to my knowledge, has associated the notion of returns to scale with firm size in this literature.

b. The lack of meso-foundations in the Evolutionary theory (Dopfer, Foster and Potts, 2004). The approach in this dissertation shows that the meso-perspective of the growth phenomenon can redeem the relationship between firm size and innovation as an important stylised fact of growth without undermining the importance of the knowledge base and technological regimes in the determination of them both. Besides, such an approach has the advantage of eliminating the excessive complications brought by the randomness of innovation process at the firm level. That is, instead of a path-dependent process with stochastic outcome, one can define growth as a cumulative process guided by the level of sectoral investment, where the level of concentration of the market-structure gives a clear idea of the technological gap (provided that the technological parameters are known).

This dissertation reinforces the idea that economic units (firm, sectors) are non-homogeneous, making the process of structural change (in either analytical level) indissociable from growth. A corollary of this condition is that the path of development can be recovered from the 'imprints' left by the development process in the sectoral market-structure and sectoral composition of the economy. By highlighting the relevance of the allocation problem and the concomitance of the multi-level process of development and structural change, this dissertation proposes an original perspective of the problem, capable of explaining the divergent growth trajectories.

At least one of these implications deserves a closer look: firms and sectors are immersed in different layers of the productive process, each with its own rules and variables. Yet, these are not independent one from the other, and the actual key for understanding the growth process rests in the interaction between these layers. As supply and demand exercise different roles at each of these layers, economic policies should focus on keeping them balanced, avoiding either constraint to bind. For instance, a country where demand develops faster than supply will de-concentrate and eventually miss potential technological gains that would enable further growth. On the opposite side, a country where demand does not grow in pace with supply will consolidate its industries and, although presenting high levels of productivity in some activities, will never translate that into the development of the productive structure, missing more gains in both production and income.

According to the results in dissertation, shocks in either demand and/or supply policies can raise the country's level of income. However, because these policies may shorten the transformation process, they can induce a structural lock-in, taking the economy to a slower long-term equilibrium growth rate. The demand policy can even have a negative effect, depending on the level of structural complexity of economy. This study showed that the effectiveness of economic policies depends on a fine combination of shocks in demand and supply at each level of development. A redistributive policy that expands the consumption at lower levels of development could reduce the potential development of sectors (which at this point is yet far from its maximum productivity level) and stimulate the demand for products that the economy cannot produce in competitive terms due the low number of capabilities internalised, increasing the external dependence. On the other hand, a policy oriented to the development of specific chains of production and sectors, which might promote the full utilisation of the benefits of scale economies, only makes sense at lower levels of development. A demand policy would have better results at intermediate levels of development.

This dissertation opens a series of new questions. One interesting aspect for future research is, in light of these findings, searching for an answer for what leads to capital deepening and what leads to capital reallocation within and across sectors? Although the economic literature in its broad spectrum has thoroughly investigated what countries do as they accumulate capital (Barro and Sala-i-Martin, 1992), the question on what determines the shifting of factors from labour-intensive to capital-intensive sectors (factor reallocation) and what determines the increase in the capital/labour ratio at every sector (capital deepening) were not clearly addressed. Exploring further the point where the effects of the sectoral consolidation spill over firms within and across the sectors of the economy, for instance, is a possible strategy in this way. This can reveal interesting conclusions on what prompts the sophistication of the productive structure. One hypothesis is that the income distribution might have an important role in this process, with a direct impact on the country's trajectory of development. As discussed, the final impact of growth in a country will depend on the dynamicity of both supply and demand, which depend on the income level and on the distribution of income, consumption patterns, and a series of institutions and policies impacting either productivity and/or consumption.

One important limitation of this work refers to the unavailability of data on stock of capital both at the firm- and sectoral-levels. Even though the approach tried to minimise this problem with alternative measures and reconstituting the stock of capital by perpetual inventory method, the robustness of the analysis can certainly be improved with consistent data on capital. The approach would also benefit from the adoption of longer time series and comparable intra- and inter-sectoral databases. The countries, sectoral breakdown and period were different in most cases analysed, impacting on the robustness of the approach and its conclusions. An alternative approach to tackle the lack of such integrated databases would be replicating the analysis over a longer period for a single developing country, since this can show the singular instead of a generic path of development.

The approach in this dissertation can be expanded in several directions:

(i) Although Chapter 9 argued that there is an excess of information provided by the two layers, so that the development process can also be represented in a one-level model, the adoption of agent-based and complex models could improve considerably the analysis. While less clear in their mechanisms, these methods could improve the understanding of the interactions between these layers and help exploring scenarios with different constraints binding.

(ii) Whereas the advantages of size represented in the returns to scale are logically consistent with our expectations, the reverse causality also deserves some investigation. Both the causes of the phenomenon and cross-sector differences are yet unclear.

(iii) Exploring innovation surveys in combination with production data could reveal important patterns and clarifying the foundations of the structural sophistication process. Indeed, despite derived from micro-evolutionary studies, the complexity theory has yet to explore the links between innovation variety and productive complexity.

(iv) Another important aspect for future research is to investigate the impact of trade openness in the economic growth. Such an approach could help revealing the interference of external constraints, such as the influence of balance-of-payment in the internal constraints, and the impact of the openness level on the development of both the level of returns to scale and structural competitiveness.

To conclude, this dissertation brings important contributions to economic growth theory, in special for highlighting the importance of demand and supply requisites in the process of growth, here explained with inputs of the Evolutionary and Kaldorian approaches. The multi-level allocation problem is shown to be indissociable from growth itself and, as a corollary, the structural transformation the key for understanding growth and development. The analysis can be improved in several ways, but the results seem consistent and generate a number of original implications for improving development plans.

APPENDIX 1: The UNIDO (inter-sectoral) database

Data for the inter-sectoral analysis in this dissertation are from the third version of the UNIDO Industrial Statistics Database (INDSTAT)[222], which comprises two datasets: (i) the INDSTAT4, where the data are arranged at the 4-digit level of ISIC - Revision 3; and (ii) the INDSTAT2, where the data are arranged at the 2-digit level of ISIC - Revision 3. These comprise unbalanced annual information on the following variables for formal manufacturing activities[223]: (i) labour inputs, (ii) gross output, (iii) value added, (iv) production volume, and (v) gross formation of fixed capital. In total, the combined dataset presents 20 years of data (1990-2009) for 131 countries. The sectoral disaggregation comprises 127 manufacturing sectors at the 4-digit and 23 sectors at the 2-digit level[224].

Data preparation and sample selection

The availability and quality of disaggregated data is a first-order limitation for the analysis of the allocation problem in its multiple levels. A number of strategies to assure the validity of the results are necessary and some drawbacks are, though, impossible to deal with, including the traditional 'classification problem', related to the fact that differences in quality are not visible in the aggregations. At the same time, new products do not generally substitute old ones, but increase the variety of substitutes grouped in the same classification, even though the demand elasticities for these goods differ, as reinforced by Kuznets (1971, p. 315). An implication is that "*both the true rate of shift in production structure and its connection with the high rate of aggregate growth are grossly underestimated*" (Kuznets, 1971, p. 315).

To make it possible to compare the data across time, a price index was generated. Since no suitable deflator is available in the database, the price index was constructed by using the data for industrial production and the volume index provided in the original database. The problem with this strategy is that the information on production volume was only available for the 2-digit database. In order to make the more disaggregated database compatible, it was assumed that the index for the 2 digit ISIC

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222 Available at <https://www.unido.org/researchers/statistical-databases>. Access in 18/02/2014.
223 Accounts of informal activities within the sectors depend on the country specific methods of tracking the information in the informal economy. The extent to which the database comprises the informal activity heavily depends on the quality of national sources.
224 Available at <https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf>. Access in 08/03/18.

suits all sub-activities within its own category[225]. To avoid the exclusion of some sectors, when the volume information was missing at the 2 digit level, the 1 digit value was used. The reconstitution of the volume index series also involved the interpolation/extrapolation of temporal data for the same country and sector in specific cases, following Fagerberg (2000). For many important countries, however, no volume data are available at all (e.g. China), determining their exclusion from the final database[226].

The final sample was defined by a series of discretionary restrictions. Out of the 131 countries in the original combined dataset, only 72 countries presented at least 10 years of data for all the basic variables: employment, output and price index. Other 7 countries were excluded due to the misrepresentation of sectors. Once the number of sectors is directly connected to the representativeness of each sector in the country series, this variable was checked for each country and year and only kept in exceptional cases, when the series were extremely consistent over time. This was the case of Israel, Brazil, Argentina, Panamá and Qatar, countries with less than 50 sectors represented.

The next step involved the use of functions and graphical analysis to check for inconsistencies in each of the 65 countries. Both the sectoral representativeness (annual number of sectors represented), and the sectoral employment, output, productivity, and price index series were checked. As a conservative measure, in order to maintain the sectoral representativeness and avoid a discreet and non-random exclusion of sectors with problematic data, whenever an inconsistency was identified, the country's year data was excluded. Except for very specific cases, sectoral

[225] An alternative price index was generated for each country at the 4-digit SITC level by using data of international trade provided by the UN-COMTRADE (2013). International trade data are generally much more reliable and ubiquitous compared to production data, but as long as imports and exports are extremely volatile (besides depending on several other country macroeconomic, political, institutional variables and specially the openness level - in some cases certain sectors have special tax regimes), they can prompt a false perspective of both the country real productive structure and price level. To assure this was a good strategy, the COMTRADE price index was compared to the UNIDO price index for the 2-digit level of industries. Results however were not directly comparable as both the level of the indicators and their variability are completely different in both series. Due to the good fit of the data reconstituted with the volume index information, this was the chosen strategy.

[226] An alternative would be adopting the national aggregated price index as the deflator, but as long as the covariance of such series and for some selected countries were found to be low, the strategy was discarded. In fact, the reconstitution of the price index with the available volume data has showed important patterns worldwide for some sectors. Adopting a general index, which also includes other non-industrial sectors, would invalidate the results for these countries.

inconsistencies were found to be more of a batch problem than a specific sectoral problem. Thus, the exclusion of the temporal information was generally inevitable.

The last step involved the comparison between the original 2-digit data with an aggregation of the 4-digit data into 2-digit sectors. As the source of information in each of the datasets might vary, this strategy revealed itself as the ultimate quality control. In fact, divergences are a clear indicator that the country's information is not trustworthy. Several inconsistencies were identified by this strategy and a few countries were excluded from the final sample due to it. Even though no poor countries has passed the above tests, at least no discreet modification was done in the series of the remaining countries, besides the exclusion of temporal information, which is not so relevant due to the number of years represented[227].

The final database consists thus of sectoral and aggregate labour productivity, output, price and employment statistics for 46 countries, covering the period of 1991-2009. Out of the total sample, 28 are high-income countries, 5 of these non-OECD, 12 upper-middle income countries and 5 low-middle income countries. Even though the information is not balanced across either sectors or countries, a total of 125 sectors were preserved from the original sectoral breakdown (the recycling sector (id.37) and subsectors were excluded due to the fact that for some countries it was representing the overall results). Table A1 presents the cross section and averages values of the key variables.

[227] For several countries, the years 2007, 2008 and 2009 were particularly problematic.

Table A 1: Sample and basic statistics

Country	Income group	Sample: Initial year	Sample: End year	Average number of sectors	Log average Prod	Prod standard deviation (% country average)	Average annual prod growth	Average annual price growth	Average annual output growth	Average annual Employment growth	Log prod sec min	Log prod sec max	Log internal gap (min/max %)
East Asia & Pacific													
South Korea	High income: OECD	1991	2006	124	7.31	1.52	6.08%	4.96%	6.35%	0.23%	6.63	8.48	78.10%
Japan	High income: OECD	1994	2007	120	7.65	1.55	3.63%	-1.78%	1.37%	-2.17%	6.83	8.73	78.20%
Australia	High income: OECD	1996	2001	84	7.21	0.86	1.89%	-8.06%	1.86%	0.01%	6.66	8.00	83.17%
Malaysia	Upper middle income	2000	2008	116	6.94	2.59	1.74%	8.61%	5.17%	3.48%	6.11	8.38	72.89%
Indonesia	Lower middle income	1998	2009	113	6.42	1.23	1.38%	12.02%	1.69%	0.48%	5.07	7.31	69.41%
Singapore	High income: nonOECD	1996	2003	72	7.35	2.27	0.41%	0.40%	-0.56%	-0.95%	6.58	8.61	76.41%
Europe & Central Asia													
Ukraine	Lower middle income	2000	2009	123	6.16	1.17	9.94%	10.25%	5.24%	-4.50%	5.22	7.14	73.17%
Ireland	High income: OECD	1991	2007	77	7.38	1.71	9.60%	-0.62%	10.36%	0.70%	6.55	8.43	77.67%
Latvia	High income: nonOECD	1990	2007	91	6.39	1.51	6.78%	23.44%	2.72%	-3.81%	5.35	7.49	71.40%
Czech Republic	High income: OECD	1995	2004	64	6.59	0.89	6.50%	3.77%	4.95%	-1.46%	6.05	7.47	81.06%
Bulgaria	Upper middle income	1996	2009	85	6.32	1.23	6.33%	15.29%	6.54%	-0.15%	5.49	7.27	75.56%
Hungary	Upper middle income	1998	2009	119	6.76	1.25	6.11%	8.74%	5.01%	-1.08%	5.92	7.68	77.02%
Russia	High income: nonOECD	2000	2009	30	6.37	1.01	5.81%	24.38%	3.10%	-2.50%	5.42	7.06	76.82%
Finland	High income: OECD	1995	2007	112	7.24	0.78	5.42%	0.23%	6.06%	0.60%	6.74	8.08	83.38%
Austria	High income: OECD	1995	2008	103	7.22	0.53	4.34%	4.35%	4.64%	0.30%	6.68	7.74	86.30%
Denmark	High income: OECD	1995	2008	87	7.16	0.75	3.92%	-3.23%	3.30%	-0.58%	6.78	7.98	85.05%
Slovenia	High income: OECD	1995	2007	115	6.87	0.67	3.70%	-1.72%	4.19%	0.41%	6.22	7.58	81.96%
UK	High income: OECD	1993	2007	117	7.31	1.22	3.68%	6.01%	0.36%	-3.03%	6.81	8.45	80.57%
Sweden	High income: OECD	1990	2007	100	7.21	0.46	3.66%	3.37%	4.10%	0.61%	6.63	7.69	86.18%

Cont. Table A1

France	High income: OECD	1996	2008	121	7.34	1.27	3.01%	3.98%	1.16%	-1.75%	6.73	8.47	79.44%
Portugal	High income: OECD	1996	2008	115	7.03	1.72	2.76%	10.85%	1.08%	-1.60%	6.28	8.38	74.88%
Belgium	High income: OECD	1995	2008	109	7.42	1.03	1.79%	-0.80%	1.49%	-0.28%	6.82	8.40	81.14%
Netherlands	High income: OECD	1995	2008	93	7.30	0.68	1.60%	2.39%	1.64%	0.10%	6.77	8.23	82.20%
Estonia	High income: OECD	2003	2009	64	6.64	0.78	1.20%	12.20%	-2.28%	-4.02%	5.87	7.32	80.21%
Norway	High income: OECD	1994	2008	102	7.24	0.67	0.93%	6.84%	1.04%	0.13%	6.71	7.96	84.32%
Germany	High income: OECD	1995	2009	118	7.28	1.07	0.66%	3.12%	0.97%	0.39%	6.68	8.35	79.93%
Spain	High income: OECD	1993	2008	121	7.19	1.26	0.62%	6.62%	1.46%	0.85%	6.68	8.41	79.41%
Turkey	Upper middle income	1992	2001	118	6.92	1.08	-0.87%	-2.58%	1.68%	2.27%	5.89	8.14	72.33%
Italy	High income: OECD	1992	2008	121	7.33	1.18	-1.22%	8.85%	0.49%	2.41%	6.82	8.44	80.77%
Latin America & Caribbean													
Mexico	Upper middle income	1994	2000	98	7.00	0.79	4.95%	3.36%	8.17%	3.06%	6.32	7.55	83.71%
Bolivia	Lower middle income	1995	2001	83	6.56	2.26	3.15%	-5.57%	1.37%	-1.73%	5.22	7.86	66.43%
Panama	Upper middle income	1992	2005	43	7.07	2.62	2.57%	0.82%	1.39%	-0.97%	6.20	8.29	74.74%
Colombia	Upper middle income	2000	2005	111	6.89	1.29	2.57%	9.50%	2.72%	0.15%	6.02	7.91	76.14%
Peru	Upper middle income	1995	2003	119	6.76	1.81	0.86%	1.73%	2.39%	1.52%	4.39	7.93	55.39%
Ecuador	Upper middle income	1995	2008	100	6.79	1.47	-0.66%	4.88%	3.00%	3.82%	5.43	7.80	69.71%
Argentina	Upper middle income	1994	2001	26	7.20	1.41	-1.39%	-2.50%	-0.83%	0.63%	6.54	8.08	80.97%
Uruguay	High income: nonOECD	1998	2007	58	7.00	1.91	-2.00%	1.46%	4.95%	8.15%	5.93	8.13	72.94%
Brazil	Upper middle income	1996	2007	33	7.03	1.33	-3.02%	-10.22%	-1.38%	1.71%	6.08	7.91	76.84%
Middle East & North Africa													
Israel	High income: OECD	1995	2008	24	7.24	1.50	4.14%	4.50%	4.31%	0.07%	6.70	8.13	82.43%
Morocco	Lower middle income	2000	2009	114	6.75	1.49	2.77%	12.64%	3.06%	0.53%	5.47	7.79	70.27%
Qatar	High income: nonOECD	2000	2006	35	6.88	1.72	2.02%	22.12%	8.94%	10.58%	5.87	7.84	74.92%
Jordan	Upper middle income	1994	2009	77	6.66	1.23	-1.81%	7.73%	1.89%	4.60%	5.48	7.57	72.36%

Cont. Table A1

	North America												
USA	High income: OECD	1997	2008	115	7.54	1.12	3.97%	1.83%	1.14%	-2.62%	6.95	8.48	81.99%
Canada	High income: OECD	1990	2008	105	7.37	2.00	2.23%	1.24%	2.06%	-0.14%	6.68	8.65	77.24%
	South Asia												
India	Lower middle income	1998	2008	122	6.56	1.35	5.35%	7.24%	9.08%	3.65%	5.48	7.60	72.03%
	SAMPLE AVERAGE	**1995**	**2007**	**93**	**7.00**	**1.32**	**2.82%**	**4.95%**	**3.05%**	**0.40%**	**6.17**	**7.98**	**77.27%**

Source: author's own elaboration (data from UNIDO)

APPENDIX 2: The SDBS (intra-sectoral) database

Different from the vast majority of studies in economics, this thesis is not confined to one specific analytical level, but involves the interaction of elements at the firm, sector and country levels. The completeness of the dataset and the consistency of the data across each of these units is thus fundamental as the misrepresentation of firms and/or sectors, for instance, can bring about a number of irreconcilable distortions in more aggregated levels. These add up to the usual questions on the quality of comparability of the data for different units and periods.

With this in mind, data for the intra-sectoral analysis in this dissertation are sourced in the Structural and Demographic Business Statistics (SDBS) database published by the Organisation for Economic Cooperation and Development (OECD)[228]. This database features the data collection of the OECD Statistics Directorate for the period between 1990 and 2010 relating to a number of key variables described in Table A2 broken down at the 4-digit International Standard of Industrial Classification (ISIC - Revision 3), including the service sector, and 5 firm size classes (National Standard Classification – NSC). Table A3 presents the size classes.

Table A 2: SDBS variables: % of non-missing for the 4-digit dataset

Indexes		Num. Obs	%
prod	Production	447751	65.95%
valu	Value added	167032	24.60%
gops	Gross Operating Surplus	375336	55.29%
gitg	Gross investment	373050	54.95%
empn	Total employment (number engaged)	574872	84.68%
ings	Total Purchases of Goods and Services	407028	59.96%
wase	Wages & salaries of employees	445740	65.66%
emp	Number of employees	483633	71.24%
ehou	Hours worked by employees	292884	43.14%
entr	Number of enterprises	600217	88.41%
rdem	Total number of R & D personnel	200349	29.51%
rdva	Total intra-mural R & D expenditure	199085	29.33%

Source: author's own elaboration (data from the SDBS)

[228] Available at < http://stats.oecd.org/index.aspx?r=974870>. Access in 21/02/16.

The dataset includes all OECD countries plus a number of other highlighted economies, totalising 42 developed and developing countries. The panel is not balanced though. Most series only range from mid 1990's until mid 2000's[229]. On the cross-section, the sectoral breakdown also varies from country to country. Whereas for some countries as many as 243 sectors are represented (4-digit ISIC Revision 3), others only feature a few aggregated sectors (1-digit to 2-digit ISIC). Finally, key variables are not available for all countries. See Table A4 for the cross-section and temporal availability of the data.

Table A 3: Size classes

Size Class	Number of employees
NSC-1	1 to 9
NSC-2	10 to 19
NSC-3	20 to 49
NSC-4	50 to 249
NSC-5	250+

Source: SDBS database

Data preparation and sample selection

Among the advantages of the SDBS database, one should highlight: firstly and foremost, it presents comparable data for a great number of countries and years. Secondly, because the data is disaggregated by the 4-digit ISIC industries, the scope for exploring the composition of sectors within different economies is amplified. Thirdly, the five firm size categories, if not the ideal, at least enables the analysis of the change in the intra-sectoral composition. Finally, the dataset is relatively consistent both within as well as between countries.

Nevertheless, the SDBS database presents a number of limitations. For these not to render the analysis inconsistent, different strategies were necessary. Firstly, because it does not include a measure of capital stock, total factor productivity can only be estimated by indirect methods[230]. Secondly, neither a price statistic nor a measure of output volume are included in the database, making it impossible to separate real/quality changes from price effects at the firm and sector levels[231]. The problem is attenuated though by the fact that the majority of countries in the sample

[229] 97% of the responses for output and labour employment are for the period between 1995 and 2007.
[230] The perpetual inventory method is used to estimate the capital stock in Chapter 6.
[231] In fact a number of studies use the correlation between salaries and wages changes and productivity change to make assertions on product quality change at the firm level (Fingleton, 2003).

are developed, making the hypothesis of even intra-sectoral distribution of technology less odd, and share the same currency, facilitating comparisons at the country level. Thirdly, the excessive number of missing information undermines the use of some of the variables[232]. Less than 25% of the sample units present information on value added, for instance. Furthermore, the missing information is not evenly distributed across countries, sectors and size categories, what can prompt a bias in the results in case this variable is adopted for the whole sample calculations of productivity.

A series of logic restrictions was implemented in order to preserve the data consistency across units and years. For each country, logical functions and graphical analysis helped determining the sectoral and intra-sectoral reliability of the information. As a conservative metric, in order to keep the sectoral and intra-sectoral representativeness, avoiding a discreet and non-random exclusion of information, especially of sectors and firms, whenever inconsistencies were identified, the whole temporal information (year) was discarded. Except for specific cases though, the outliers detected either by analytical measures or the application of the method of Bacon (Billor, Hadi, and Velleman, 2000) were from transformation, oil and energy-based sectors. These presented high levels of productivity and great volatility through time, but were kept in some exercises for this abnormal characteristics seems to be consistent across all countries in the sample. Besides these, only Turkey and Mexico data presented anomalies that required further measures. For the first, the most recent data were dropped due to a structural break detected between 2001 and 2003 (2002 data is missing). The two series, 1994-2001 and 2003-2006, are internally consistent, but cannot be harmonised between themselves. Thus, the exclusion of the latter was inevitable. Mexico's reports for small firms, in turn, suffered from the low representativeness across sectors and great volatility across years (more than 10 times the effect on other size class of firms). Therefore the whole size class of small firms was discarded.

To increase degrees of freedom and make international comparisons possible, this thesis opted to work with the 2-digit ISIC sectoral breakdown[233]. The 1-digit dataset was used to validate the information on the 2-digit dataset. As information is much more complete and abundant for more aggregated levels (in fact, the sources and methods of data collection for each aggregation level may

[232] See Table A2.

[233] The vast majority of countries in the database release information for this classification, which is not the case for the 4-digit ISIC. In fact the latter panel was much more unbalanced both in cross-sectional (sectors and countries) and temporal terms.

vary within the countries), this was compared year by year with the 2-digit dataset and anytime divergences beyond the 95% confidence interval were discovered, the data for the year/country excluded from the final sample. The final sample comprises a total of 35 countries with unbalanced data between 1990 and 2007 at the 2-digit ISIC sectoral disaggregation.

Table A 4: Average firm size composition by country

COUNTRY		SAMPLE INITIAL YEAR	SAMPLE END YEAR	Variables	Size categories NSC-1	NSC-2	NSC-3	NSC-4	NSC-5	Total	GAP (SD %)
				Prod	0.04	0.04	0.03	0.02	0.01	0.03	0.92
Albania	ALB	1998	1998	L	22.33%	8.31%	13.65%	36.99%	18.71%	1	7.73
				Q	30.99%	12.40%	16.48%	32.61%	7.52%	1	9.44
				Prod	0.13	0.09	0.10	0.08	0.11	0.11	1.35
Australia	AUS	2005	2006	L	39.15%	9.64%	9.76%	13.68%	27.76%	1	10.77
				Q	44.79%	8.04%	9.16%	9.65%	28.36%	1	13.26
				Prod	0.10	0.11	0.14	0.19	0.25	0.18	4.95
Austria	AUT	1995	2007	L	14.49%	11.26%	14.41%	26.63%	33.22%	1	7.94
				Q	8.22%	6.91%	10.72%	27.93%	46.22%	1	13.66
				Prod	0.14	0.18	0.22	0.28	0.41	0.27	8.01
Belgium	BEL	1995	2007	L	24.19%	9.79%	16.20%	19.70%	30.12%	1	5.72
				Q	12.65%	6.56%	13.28%	20.85%	46.66%	1	11.01
				Prod	0.06	0.05	0.05	0.06	0.11	0.08	1.56
Bulgaria	BGR	2002	2006	L	10.94%	7.62%	12.86%	30.71%	37.86%	1	11.43
				Q	8.61%	5.53%	9.24%	24.05%	52.57%	1	14.65
				Prod	0.08	0.11	0.12	0.13	0.10	0.10	1.71
Cyprus	CYP	2000	2007	L	42.63%	13.40%	12.49%	13.03%	18.44%	1	9.05
				Q	33.59%	15.46%	15.06%	17.07%	18.82%	1	5.43
				Prod	0.06	0.08	0.10	0.12	0.19	0.13	3.54
Czech Republic	CZE	1997	2007	L	20.55%	7.59%	10.73%	24.05%	37.07%	1	8.67
				Q	9.78%	4.77%	8.50%	22.18%	54.77%	1	14.78
				Prod	0.13	0.11	0.12	0.15	0.18	0.14	1.99
Denmark	DEN	1996	2007	L	17.52%	11.27%	15.42%	23.41%	32.37%	1	6.31
				Q	15.52%	8.36%	12.90%	23.84%	39.37%	1	9.28
				Prod	0.06	0.07	0.08	0.11	0.09	0.09	1.47
Estonia	EST	1995	2007	L	14.83%	13.00%	19.85%	30.46%	21.87%	1	4.93
				Q	10.71%	10.33%	18.00%	38.77%	22.19%	1	8.38
				Prod	0.13	0.14	0.16	0.20	0.31	0.23	5.49
Finland	FIN	1995	2007	L	16.82%	8.02%	10.63%	20.82%	43.71%	1	9.81
				Q	9.29%	4.76%	7.43%	18.34%	60.18%	1	16.07
				Prod	0.11	0.13	0.16	0.19	0.31	0.21	5.79
France	FRA	2000	2007	L	19.94%	8.53%	13.89%	18.85%	38.79%	1	7.52
				Q	9.92%	5.06%	10.43%	17.33%	57.25%	1	14.90
				Prod	0.09	0.14	0.13	0.17	0.26	0.19	4.57
Germany	GER	1995	2007	L	12.36%	9.18%	10.68%	23.05%	44.72%	1	11.11
				Q	5.60%	5.19%	7.34%	21.04%	60.83%	1	16.75
				Prod	0.08	0.12	0.15	0.16	0.26	0.12	4.56
Greece	GRE	1996	2007	L	65.15%	6.86%	7.95%	12.01%	8.03%	1	18.06
				Q	44.89%	6.91%	10.35%	17.44%	20.41%	1	10.12
				Prod	0.05	0.07	0.08	0.10	0.22	0.13	4.72
Hungary	HUN	1997	2007	L	19.37%	8.55%	11.30%	22.76%	38.01%	1	8.31
				Q	6.86%	4.33%	6.91%	18.17%	63.72%	1	17.49

Cont. Table A4

Ireland	IRE	1998	2007	Prod	0.13	0.14	0.20	0.30	0.40	0.29	9.33
				L	4.42%	6.99%	22.59%	34.12%	31.88%	1	11.44
				Q	1.94%	3.23%	15.10%	34.36%	45.37%	1	15.89
Israel	ISR	1995	2007	Prod	0.09	0.10	0.12	0.17	0.21	0.15	4.20
				L	27.26%	8.94%	11.60%	21.56%	30.64%	1	7.79
				Q	17.46%	6.68%	10.83%	26.70%	38.32%	1	10.01
Italy	ITA	2004	2010	Prod	0.11	0.15	0.21	0.28	0.36	0.20	7.81
				L	35.23%	15.58%	14.90%	16.33%	17.96%	1	6.09
				Q	19.03%	11.60%	15.28%	22.28%	31.81%	1	5.64
Japan	JPN	1996	2007	Prod	0.09	0.12	0.16	0.24	0.43	0.25	10.22
				L	11.49%	10.95%	17.95%	29.36%	30.25%	1	7.84
				Q	4.00%	5.41%	11.38%	28.12%	51.08%	1	15.68
Korea	KOR	1995	2007	Prod	0.11	0.14	0.17	0.24	0.42	0.26	9.31
				L	9.99%	12.45%	19.42%	23.91%	34.23%	1	7.26
				Q	4.64%	6.96%	12.89%	22.49%	53.02%	1	14.20
Latvia	LVA	1990	2006	Prod	0.07	0.07	0.07	0.08	0.08	0.08	0.67
				L	11.52%	11.46%	18.07%	37.94%	21.01%	1	7.58
				Q	10.39%	10.20%	17.01%	41.31%	21.10%	1	8.96
Lithuania	LTU	1995	2007	Prod	0.12	0.13	0.15	0.18	0.26	0.20	4.20
				L	8.90%	7.36%	14.24%	33.76%	35.74%	1	11.80
				Q	5.33%	4.90%	11.18%	31.85%	46.73%	1	15.43
Luxembourg	LUX	1995	2007	Prod	0.14	0.15	0.13	0.14	0.16	0.15	0.95
				L	9.98%	10.03%	20.35%	31.71%	27.93%	1	7.99
				Q	9.06%	7.24%	16.99%	30.03%	36.68%	1	10.68
Malta	MLT	1998	2007	Prod	0.06	0.12	0.13	0.08	0.03	0.06	3.27
				L	38.79%	6.85%	10.28%	9.78%	34.30%	1	13.24
				Q	36.55%	12.45%	21.61%	14.30%	15.08%	1	7.27
Mexico	MEX	1995	2007	Prod	-	0.04	0.05	0.16	0.23	0.12	7.44
				L	-	24.63%	32.98%	12.06%	30.32%	1	6.65
				Q	-	9.69%	16.12%	14.61%	59.58%	1	17.29
Netherlands	NLD	1999	2007	Prod	0.14	0.17	0.20	0.26	0.35	0.24	6.32
				L	21.68%	11.09%	17.00%	23.99%	26.25%	1	4.76
				Q	12.19%	8.13%	13.83%	25.80%	40.05%	1	10.34
Norway	NOR	1999	2007	Prod	0.13	0.15	0.17	0.21	0.23	0.19	3.55
				L	23.42%	11.87%	12.55%	23.42%	28.74%	1	6.23
				Q	16.07%	9.56%	11.69%	27.73%	34.95%	1	9.07
Poland	POL	1996	2007	Prod	0.07	0.09	0.10	0.11	0.20	0.13	3.62
				L	25.10%	3.82%	8.79%	26.75%	35.55%	1	10.96
				Q	12.77%	2.55%	6.38%	22.83%	55.47%	1	15.32
Portugal	POR	2004	2007	Prod	0.07	0.08	0.10	0.12	0.21	0.11	3.86
				L	31.87%	11.89%	16.80%	24.95%	14.48%	1	6.73
				Q	22.16%	8.75%	14.46%	27.06%	27.57%	1	6.72
Romania	ROM	1996	2007	Prod	0.04	0.05	0.05	0.04	0.07	0.06	0.77
				L	5.64%	4.06%	7.56%	22.74%	60.01%	1	17.10
				Q	3.98%	3.56%	6.51%	17.37%	68.58%	1	19.43
Slovak Republic	SKR	1997	2006	Prod	0.08	0.07	0.08	0.08	0.13	0.10	1.49
				L	6.80%	7.03%	7.08%	27.66%	51.43%	1	15.64
				Q	4.91%	4.89%	5.39%	21.73%	63.08%	1	17.92
Slovenia	SLO	2000	2007	Prod	0.08	0.12	0.11	0.13	0.18	0.14	2.14
				L	19.40%	5.84%	8.58%	24.21%	41.96%	1	10.47
				Q	11.59%	5.14%	7.28%	22.12%	53.87%	1	14.40
Spain	SPA	2000	2007	Prod	0.09	0.13	0.16	0.22	0.36	0.18	7.86
				L	27.78%	15.49%	19.93%	18.51%	18.29%	1	3.11
				Q	14.21%	10.62%	17.31%	22.06%	35.80%	1	7.14
Sweden	SWE	1996	2007	Prod	0.11	0.14	0.15	0.19	0.27	0.20	4.50
				L	19.50%	8.39%	10.97%	20.47%	40.68%	1	8.46

Cont. Table A4

				Q	10.83%	5.83%	8.47%	19.88%	54.99%	1	14.00
Turkey	TUR	1994	2001	Prod	0.03	0.06	0.10	0.15	0.24	0.10	6.20
				L	50.83%	6.13%	8.32%	13.04%	21.69%	1	13.01
				Q	16.29%	3.79%	8.66%	19.31%	51.95%	1	12.78
United Kingdom	UK	1996	2007	Prod	0.13	0.13	0.14	0.18	0.28	0.20	4.51
				L	19.04%	8.94%	11.84%	22.28%	37.91%	1	8.08
				Q	12.38%	5.99%	8.69%	20.37%	52.56%	1	13.17
Global		**1990**	**2007**	**Prod**	**0.09**	**0.11**	**0.13**	**0.16**	**0.23**	**0.16**	**4.28**
				L	**22.03%**	**9.36%**	**13.49%**	**23.61%**	**31.52%**	**-**	**9.20**
				Q	**14.62%**	**7.12%**	**11.67%**	**23.73%**	**42.85%**	**-**	**12.33**

Source: author's own elaboration (data from the SDBS)

APPENDIX 3: Panel Data

Panel data (longitudinal data) analysis present a series of advantages over cross-section analyses, especially because it accounts for the intertemporal dependence of the events studied. The inclusion of the temporal data in the analysis also improves the accuracy of the estimates due to the increased the number of observations[234]. A second advantage of panel data models is the possibility of estimating fixed-effects models, which enable, without the aid of traditional instruments, the estimation of the parameters even when there is non-observed individual heterogeneity in the data[235], which would otherwise lead to a bias due to omitted variables[236]. Besides, panel data enable the use of lagged dependent variables among the regressors, allowing the estimation of dynamic models. Finally, panel data methods provide an excess of available conditions for estimation, leading to an abundance of instruments, even with non-iid errors.

Since most of the empirical exercises in this dissertation rely on longitudinal data, this appendix aims at discussing the use of the method for different strategies of identification. The next subsection introduces the panel data models, focusing on the different hypotheses towards the individual unobserved heterogeneity. It should be emphasised that the estimators of each model are not discussed in detail, whereas attention is drawn to the differences between OLS and GMM estimators. The last part discusses some usual problems with pooled data and the limitations of such an approach.

A general panel data model and its estimators

Equation (A1) represents the general linear regression model where both the intercept and slope vary with individuals and time:

$$y_{it} = \alpha_{it} + x'_{it}\beta_{it} + u_{it}, \quad i = 1, \dots, T \qquad \textit{(A1)}$$

[234] However, for the statistical inference to be valid, it is necessary to control for the correlation that the temporal data can yield.
[235] Provided that non-observed specific individual effects are additive and time invariant.
[236] If one treat any individual non-observed heterogeneity to be distributed independently of regressors, one may alternatively use a random effects model. This stronger hypothesis, however, is usually rejected for economic data (Cameron and Trivedi, 2005).

where y_{it} is a scalar dependent variable, x_{it} is a vector K x 1 of independent variables, uit is the scalar disturbance term, i indexes the individuals in a cross-section and t indexes the time. A regressor x_{it} can either be invariant in time, so that $x_{it} = x_i \forall\ t = 1, \dots, T$, or variant in time. For some estimators only the time-varying coefficients are identified. This general model is not estimable if there are more parameters than observations. In addition, other constraints add up when α_{it} and/or β_{it}vary with i and t, in addition to constraints associated with the error term.

For panel data involves information on both individuals and time, there is a much larger array of models and estimators than cross-section data. In general, three approaches are possible with panel data. The first hypothesis assumes the absence of specific individual terms in the sample, i.e., the intercept and the inclination of the estimation do not vary with time and individuals, as common in cross-section models. In this case, one can estimate the parameters through a stacked OLS or pooled ordinary least squares (POLS).

Alternatively, a model with specific individual effect enables each cross-sectional unit to have a different intercept, although the slopes are the same.

$$y_{it} = \alpha_{it} + x'_{it}\beta + \epsilon_{it}, \quad i = 1, \dots, T \qquad (A2)$$

A first version of this model treats α_i as unobserved random variable, but potentially correlated with the observed x_{it} regressors. This variation is called Fixed-effects (FE) model. If fixed-effects are present and correlated with x_{it}, then several estimators such as Pooled OLS will not be consistent. Thus, an alternative estimation method, which eliminates α_i, is necessary to ensure the consistent estimation of β in a short panel.

The final variant model assumes that the unobserved individual effects α_i are random variables distributed independently of the regressors. The so-called Random Effect (RE) model generally includes the following additional assumptions, so that the random effects and the error term are assumed to be iid:

$$\alpha_i \sim [\alpha, \sigma_\alpha^2] \qquad (A3)$$

$$\varepsilon_{it} \sim [0, \sigma_\varepsilon^2] \qquad (A4)$$

Both FE and RE models assume random individual effects. The difference between them is in the correlation or not with the regressors. In addition, in short panels, the FE model allows only the identification of marginal effects ($\delta E[y_{it}/c_i, x_{it}] \div \delta x_{it}$) and the time-varying regressors. The RE model, in turn, allows the identification of all components of β and also the conditional expectation $E[y_{it}/x_{it}]$, but the key assumption of the RE models of $E[c_i/x_{it}]$ being constant is seen as unreachable in most practical applications. If the true model has specific individual effects correlated with the regressors, however, then the random effects analysis will lead to inconsistent estimators, invalidating the analysis. Alternative estimators, such as fixed-effects and first differences, are needed instead.

Although usually estimated by specific OLS or GLS methods, in order to enable the consistent estimation of FE or RE models with endogenous variables and/or dependent variables lagged as regressors, the hypothesis of strong exogeneity that assures the efficiency and consistency of the estimators of these models should be relaxed in each case. In this case, GMM estimators – Generalized method of moments – must be used in both models, as the latter control for the endogeneity problem[237].

This dissertation adopts the Arellano-Bond (1991) and Arellano-Bover (1995) / Blundell-Bond (1998) GMM estimators[238]. The first of these estimators – Arellano-Bond or GMM-Difference – consists of a two-step estimator. In the first step, the equation is differentiated (eliminating fixed-effects in time) and estimated by Generalized Least Squares (GLS) with lagged values of both explanatory variables and the endogenous variable as instruments[239]. These are considered good instruments, since they are not correlated with the error term of the differentiated equation. In the second step, the first difference of the estimated residues of the first step is used to reconstruct the matrix of instruments and the equation is re-estimated. Both the first and second step estimators are consistent. The

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[237] The use of instrumental variables is the standard procedure for treating endogenous regressors. One advantage of panel models over cross-section data is that we can use exogenous regressors at other time periods to instrumentalise endogenous regressors in the present period. The only complication is that we must first control for any fixed or random effects.

[238] These estimators are designed to deal with the type of model proposed in this study. In fact, the GMM-dif and GMM-sys estimators assume that: (i) the true model is a fixed-effects model; (ii) short panel (long n and small t); (iii) linear relationship between the dependent variable and the other explanatory variables; (iv) endogeneity of some regressors; (v) probable existence of heteroscedasticity and autocorrelation within individuals rather than between them.

[239] Alternatively, it is possible to use orthogonal deviations rather than to differentiate the data, in order to preserve the size of the sample in panels with gaps.

second estimator is, however, preferable to the first, since its consistency does not depend on assumptions about the distribution of the error term (Baltagi, 2008).

The GMM-DIF estimator is inefficient when the number of time periods is small relative to the number of cross-section observations, which is the case for both databases in this thesis. To correct this problem, an extension of this estimator – GMM-System or Arellano-Bover (1995) / Blundell-Bond (1998) estimator – is usually adopted. The GMM-SYS uses differentiated explanatory variables as additional instruments for estimating the level equation, in addition to lagged explanatory variables as instruments for estimating the first difference equation. This procedure creates two equations (the original and the transformed) ultimately increasing the estimator efficiency. Nevertheless, for its estimation one needs to assume the additional hypothesis that the first difference of the instrumental variables is not correlated with the fixed-effects[240].

Estimation problems and controlling strategies

The various models for panel data include error terms denoted by u_{it}. In several econometric applications, it is reasonable to assume independence of these errors over i. However, panel errors are potentially (i) serially correlated, and/or (ii) heteroskedastic. A valid statistical inference therefore requires control for both factors.

The first problem is usually treated by aggregating the temporal observation into averages for periods longer than the observation unit, reducing thus the serial correlation of the data. Regarding the second problem, a consistent White estimator for heteroscedasticity can easily be extended for short panel application, provided that the "i_{th}" observation of the error variance matrix has a finite size T x T when $N \to \infty$ (Cameron and Trivedi, 2005). In addition, one can control for potential heteroskedasticity increasing the sample. An important fact, however, is that the GMM estimator is always efficient in that it controls for heteroskedasticity.

Another commonly reported problem relates to the lack of data for all individuals at all periods (unbalanced panel). Fixed and random effects estimators, however, can be applied to unbalanced data with relatively little adjustment. Let d_{it} be an indicator equal to one if the "i_{th}" observation is observed and zero otherwise. Then, for the individual specific effects model, the FE estimator is

[240] This hypothesis is explained in Baltagi (2008) as the requirement that the dependent variable should not have a unit root. Bond *et al*. (2001) recommends the use of GMM-System in growth studies with panel data.

consistent if the strong exogeneity hypothesis becomes $E[u_{it}/\alpha_{it}, x_{i1}, \dots, x_{iT}, d_{i1}, \dots, d_{iT}] = 0$ and the RE estimator is consistent if, additionally, α_i is independent of other conditional variables[241].

Finally, although panel data presents a series of statistical advantages over both time-series and cross-section analyses, the fact that it aggregates information for very different units can bring a number of limitations for the approach. Examining whether financial structures affect economic growth, Arestis, Luintel and Luintel (2010) found that panel estimates do not match country-specific estimates, causing a biased inference. The mismatch between unit and cross-units parameters is of special concern in cross-country analyses (cf. Caselli et al., 1996; Pesaran and Shin., 2002). Indeed, the cross-country institutional heterogeneity requires a number of strategies for the estimations to be consistent. These include the choice for 2-stages GMM estimators and FE models, which have mechanisms of controlling for specific individual unobserved effects, but also the use of country and regional dummies and controlling for elements that may shape country-specific paths. These are discussed case by case in the chapters.

[241] In some cases, however, it may be desirable to convert an unbalanced panel into a balanced one, eliminating observations from individuals who do not have data for the whole period. Obviously this can reduce the efficiency of the estimation. Non-randomly missing data, for example, may exacerbate potential problems of non-representative samples. In addition, special methods are required if the absence of observations for the individual is related to the error term.

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